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McCRACKEN'S PRACTICAL NAVIGATION

— BY —

Lieutenant-Commander J. J. McCracken
U. S. Navy, Retired

Master Steam Ocean Vessels Unlimited
Graduate U. S. Naval Academy Class 1904

Dedicated to Rear-Admiral W. S. Benson, U. S. Navy, Retired; Chairman U. S. Shipping Board and Emergency Fleet Corporation

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DEDICATION

IN the dedication of my efforts towards standardization of the Practical Navigation of a vessel at sea and the reduction of labor incidental thereto, I consider it a great privilege to be able to dedicate the work to

REAR-ADMIRAL W. S. BENSON
U. S. Navy, Retired

Admiral Benson, due to his professional attainments, his great love for the American Navy, its traditions, and the Flag, and his unflinching loyalty to superior authority reached the pinnacle of the Naval profession. The Admiral's appointment as Chairman of the U. S. Shipping Board and U. S. Emergency Fleet Corporation is a civil recognition which stamps him as one of the foremost, if not the foremost, American Seaman of his generation.

J. J. McCRACKEN.

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CHAPTER A

Navigation Arithmetic

Mathematical Signs—Addition, plus +; subtraction, minus −; division ÷; multiplication ×; varies as or difference $\backsim$.

Fractions—Fractions are expressions denoting certain parts of a unit. They are of two kinds—Fractions or Vulgar Fractions and Decimal Fractions.

Vulgar Fractions—In Vulgar Fractions the number of times the unit is divided, or denominator, is written under the line; and the number of parts taken, or numerator, is written above the line. Thus $\frac{2}{3}$ indicates two-thirds, that is a unit has been divided into three equal parts and two of them have been taken. Should the numerator be greater than the denominator the fraction becomes an improper fraction, thus $\frac{10}{3}$ is an improper fraction and should be written $3\frac{1}{3}$ because in ten thirds there are three whole numbers and one third. The number $3\frac{1}{3}$ is a mixed fraction, that is has a whole number and a fraction. Multiplying or dividing both numerator and denominator of a fraction by the same number does not alter the value of the fraction thus: $\frac{2 \times 2}{3 \times 2} = \frac{4}{6} = \frac{2}{3}$, so that a fraction must be reduced to the lowest denomination thus $\frac{4}{6}$ is invariably written $\frac{2}{3}$ in mathematical work, and an improper fraction is reduced to a mixed fraction.

Decimal Fractions—A Decimal Fraction is a fraction whose denominator is ten or some power of ten and whose numerator is any number whatsoever. Mixed decimals are combinations of whole numbers and decimal fractions. Almost all mathematical calculations involve decimals of some description. Any vulgar fraction may be reduced to a decimal by multiplying the numerator by some power of ten and dividing by the denominator, and then dividing by the same power of ten used in the multiplication of the numerator.
Instead of using a line of separation for numerator and denominator, in decimal fractions, the numerator only is written and the denominator is shown by the position of a point or period called the decimal point. The decimal point separates the whole number from the decimal part of the fraction, all digits to the right of the decimal point are decimals, and to the left of the decimal point whole numbers. Since the denominator of the fraction is ten, or some power of ten, there must be one less number or digit in the numerator than in the denominator, and there may be any number less according to the value of the fraction. In order to indicate this condition in decimals enough ciphers are prefixed so that the number of digits in the numerator may always be one less than the number in the denominator. The denominator always contains the digit 1 followed by a number of ciphers equal to the digits, ciphers included in the decimal part of the fraction. Thus 18/1000 the numerator has two digits and the denominator has four, therefore, we have to prefix a cipher to 18 to make the digits one less than four and write the decimal fraction .018.
The fraction .00018 would be as follows, there are five digits, therefore, the denominator is 1 with five ciphers affixed and the fraction becomes 18/100000 or eighteen hundredth thousandths.

Addition of Decimals—Decimals are added exactly the same way as whole numbers. The numbers are set down decimal point under decimal point, and corresponding digit under corresponding digit from the decimal point. The columns are then added up and a decimal point placed in the summation directly under the decimal point in the column.

EXAMPLE

18.153	16.	.0582
3.26	8.134	10.703
9.17	.026	.0008
30.583	24.16	10.762

400028

Subtraction of Decimals—The greater number is set down first as a rule and the lesser number under it decimal point under decimal point. If the number of decimal places in the greater number are not equal to the number of decimal places in the lesser number add enough ciphers to make them both have the same number of places. Subtract them as in ordinary whole numbers placing a decimal point in the result directly under the decimal points of the numbers. If it is desired to subtract a greater number from a less the usual practice is to still subtract the lesser from the greater and put a minus sign in front of it.

EXAMPLE

31.267	38.070	5 h 10 m 18.0 s
3.9	.039	14 h 03 m 17.6 s
27.367	38.031	—8 h 52 m 59.6 s

Multiplication of Decimals—Multiply the numbers together as if they were whole numbers and point off enough decimals equal to the sum of the decimals in the two numbers. Should the result not have sufficient digits prefix ciphers until a sufficient number are obtained.

EXAMPLE

8.55	.13
3.6	.05
5.130	.0065
25.65	
30.78	

In cases where whole numbers are involved a good check is to multiply the whole numbers, as for instance eight times three are twenty-four, therefore, the answer will have two digits as whole numbers and somewhere near twenty-four in value, so when we see the digits 3078 we know at a glance the decimal point must go between 0 and 7, making 30.78.

Division of Decimals—This operation is performed in the same manner as if they were whole numbers. When the dividend has less decimals than the divisor a sufficient number of ciphers must be added to the dividend to make them equal. The number of decimals in the quotient must equal the excess of the decimals of the dividend above those of the divisor.

EXAMPLE

8.65)34.60(4	8.65)73.876(8.540+
34 60	69.20
	4676
	4325
	3510
	3460
	500

It is a good plan to check yourself by dividing the whole numbers for instance eight goes into 73 approximately nine times, therefore, when you see the quotient come out 85 etc. you know the answer is eight something so you automatically put the point after the 8.

CONVERSION OF TIME INTO ARC AND VICE VERSA

Time				Arc	
24 Hours	(h)		=	360 Degrees (°)	
1 Hour	(h)	= 60 Minutes (m)	=	15 Degrees (°)	
4 Minutes	(m)		=	1 Degree (°)	= 60 Minutes (′)
1 Minute	(m)	= 60 Seconds (s)	=	15 Minutes (′)	
4 Seconds	(s)		=	1 Minute (′)	= 60 Seconds (″)
1 Second	(s)		=	15 Seconds (″)	

Table 7 Bowditch may be used for the conversion of arc into time and vice versa, but the following is the method used by the best Practical Navigators.

Conversion of Time Into Arc—Multiply the number of hours by fifteen and to it add the whole number obtained by dividing the number of minutes by four, this will give the number of degrees; multiply the remainder from dividing the minutes of time by four by fifteen and add to it the whole number obtained by dividing the seconds of time by four, this will give the number of minutes of arc; multiply the remainder from dividing the seconds by four by fifteen gives the seconds of arc.

EXAMPLE

Convert 17 h 25 m 18.2 s into degrees, minutes, and seconds.

15	4)25(6°	4)18.2(4′
——	24	16
85	—	—
17	1	2.2
——	15	15
255°	——	——
6°	15′	110
——	4′	22
261°	—	—
	19′	33″

261° 19′ 33″ answer.

Conversion of Arc into Time—Divide the number of degrees by fifteen the whole number gives the number of hours; multiply the remainder from dividing the degrees by fifteen by four and add the whole number of minutes obtained by dividing the number of minutes of arc by fifteen, the sum is the number of minutes of time; multiply the remainder obtained from dividing the minutes of arc by fifteen by four and add the result obtained by dividing the number of seconds of arc by fifteen the sum is the number of seconds of time.

EXAMPLE

Convert 261° 19′ 33″ into hours, minutes, and seconds.

15)261(17 h		
15		
—	15)19(1 m	15)33(2.2 s
111	15	30
105	—	—
—	4	30
6	4	30
4	—	——
—	16s	
24 m	2.2 s	
1 m	——	
——	18.2 s	
25 m		

17 h 25 m 18.2 s answer

PRACTICAL EXAMPLES

(1) $19.8 + .8 + .0065 + 784$	=	?
(2) $17.6 + 2.35 + 16.1 - 22.094$	=	?
(3) $86.5 \times .065$	=	?
(4) $.068 \div 86.5$	=	?

(5) Convert 60° 14′ 07.3″ into hours, minutes, and seconds.
(6) Convert 3 h 15 m 17.6 s into degrees, minutes and seconds.
(7) Convert 7 h 08 m 11.2 s into hours and decimal fraction thereof.

CHAPTER B

Navigation Geometry--Table 2 Bowditch

Point—A point has neither length, breadth, or thickness; it indicates position only.

Line—A straight or right line is the shortest distance between two points in the same plane surface.

Circle—A circle is a plane surface bounded by a curved line called its circumference, every point of which is equi-distant from a fixed point within called the center.

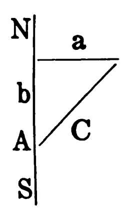
Arc of a Circle—An arc of a circle is any part of its circumference. The circumference of a circle is divided into 360 equal parts called degrees; each degree is divided into sixty equal parts called minutes of arc or minutes; and each minute is divided into sixty equal parts called seconds or seconds of arc. The linear length of the divisions vary according to the total length of the circumference. The length of the circumference depends on the length of the radius, the length from the center to the circumference and equals $2 \times 3.1416 \times$ radius of the circle.

Semi-Diameter or Radius—The semi-diameter of a circle is the distance from the center to its circumference. It is the length taken with the compass to describe the circle. The diameter is equal to twice the radius or semi-diameter.

Angle—An angle is the inclination of two intersecting lines or planes and is measured by the arc of a circle intercepted between the lines that form the angle or edges that mark the planes. The center of the circle containing the arc is at the intersection of the lines or planes.

Plane Triangles—A plane triangle is a figure contained by three straight lines in the same plane. When one of the angles is 90° the triangle is said to be right-angled. It is important to remember the following properties of a right-angled triangle for Navigational purposes—the sum of the three angles in any plane triangle are equal to 180°, and the sum of the angles about the right angle in a right-angled triangle are equal to 90°.

Trignometric Functions—The trignometric functions of the angle formed by any two lines are the ratios existing between the sides of a right-angled triangle formed by dropping a perpendicular from any point in either line on the other line. Since the ratios will be the same for any given angle wherever the triangle is formed irrespective of the length of the sides, it follows that once the angle is fixed the ratios are fixed therefore, the angle may be readily obtained from its functions and vice versa.



$\frac{a}{c}$, $\frac{\text{opposite side}}{\text{hypothenuse}}$, is called sine of the angle A, (Sin A)

$\frac{b}{c}$, $\frac{\text{adjacent side}}{\text{hypothenuse}}$, is called cosine of angle A, (cos A)

$\frac{c}{a}$, $\frac{\text{hypothenuse}}{\text{opposite side}}$, is called cosecant angle A, (cosec A)

$\frac{c}{b}$, $\frac{\text{hypothenuse}}{\text{adjacent side}}$, is called the secant angle A, (sec A)

$\frac{a}{b}$, $\frac{\text{opposite side}}{\text{adjacent side}}$, is called the tangent angle A, (tan A)

$\frac{b}{a}$, $\frac{\text{adjacent side}}{\text{opposite side}}$, is called the cotangent angle A, (cot A)

$\frac{1}{2}$ (1-cosine A), is called haversine of angle A, (hav A)

Sphere—A sphere is a solid enclosed by a surface, every point of which is equi-distant from a point within called the center. The distance from the fixed point within or center to the surface of the sphere

or circumference is called the radius or semi-diameter. It is important to remember in connection with a sphere that—A Great Circle of a sphere is a line cut from its surface by a plane passing through its center, and the radius of the circle is equal to the radius of the sphere; a Great Circle may be drawn through any two points on the surface of a sphere, and the arc cut from the surface and passing between the two points is shorter than any other line that may be drawn between the two points on the surface of the sphere; the Poles of a circle are the ends of that diameter which is perpendicular to the plane of the circle. A Small Circle of a Sphere is a section or circle cut from its circumference by a plane which does not pass through the center of the sphere.

Astronomical Triangle—The spherical triangle formed by the Great Circles cut from the surface of the Celestial Sphere by planes passing, through the Zenith of the observer and the Celestial Pole; the Zenith of the observer and some celestial body; and the Celestial Body and the Celestial Pole; is known as an Astronomical Triangle, all three planes also passing through the center of the Celestial Sphere. The sides of this triangle are called respectively the co-Latitude, Zenith Distance of the Body, and the Polar Distance of the Body.

Earth as a Flat Surface—Due to the immense size of the earth relative to any locality or the visible horizon, the surface of the earth appears to be flat. For squares of sixty miles in length the error is not appreciable in assuming the earth's surface as a plane surface, especially on the water where the surface level is practically constant.

Location and Direction.—We are accustomed to locating objects relative to each other, either by their direction from each other, or their distance from each other, or a combination of both. As certain locations become more or less common information they become points of reference, and we hear such expressions: two blocks North of the Custom House, near Washington, just outside of Paris, 3912 Main Street, etc., all of which expressions require some knowledge of location of a point of reference, direction, and distance.

At sea out of sight of land, the water looks pretty much alike all around us, and we have no Main Streets or Custom Houses to guide us. By means of the Compass we can determine very closely the angle our direction of motion makes with North or South, and by means of various instruments we can keep the distance we have gone since leaving some fixed point of departure, then by mathematics we can determine our position with reference to some standard point of reference, whose position relative to our point of departure is known.

Point of Reference for Mariners—The point of reference for Mariners is the intersection at the Earth's surface of a plane passed through the center of the earth and perpendicular to its axis of rotation, and some other plane passing through the Poles and the axis of rotation. The Great Circles cut from the Earth's surface by these planes are called respectively the Equator and Standard Meridians. For English speaking people the Meridian of Greenwich, England, is the commonly accepted Standard Meridian, and as the United States and England publish the major part of the reliable Nautical Information, we may say that the Meridian of Greenwich, England, is the standard for the World at Large.

Since but one plane can be passed through a particular point on the Earth's surface and the Poles or Axis of the Earth, every point on the Earth's surface is capable of having and does have a definite plane passing through it and the Poles of the Earth and this plane is defined or called the Local Meridian Plane.

Longitude —The angle between the Standard Meridian or Meridian of 0° Longitude and the Local Meridian is called Longitude. Its magnitude may be definitely measured by the intercepted arc of the two planes on either or both the Terrestial and Celestial Equators, and these two circles are the ones commonly used for measuring it, for the reason that they are both Great Circles. It may be measured on any other circle of the Terrestial and Celestial Spheres parallel to the Equator, and when we do Dead Reckoning we measure our change of Longitude on circles parallel to the Terrestial Equator. It is therefore measured in degrees, minutes, and seconds of arc and also under certain conditions in hours, minutes, and seconds of time, based on the assumption that 24 hours of time equals 360° of arc.

Latitude—The angular distance an observer is North or South of the Equator, measured on the Local Meridian of the Observer, is called Latitude.

Location of Position on the Earth's Surface—Due to what is known as the Law of Gravitation all observers within the Earth's influence are constrained to remain on the Earth's surface, therefore, an Observer can still be sure that Good Old Mother Earth is going to hold on to him.
If we know the Latitude of the Observer and whether North or South of the Equator his position in the Local Meridian Circle is definitely fixed, and if we know the angle between the Local Meridian and the 0° Meridian and whether East or West of the Standard or 0° Meridian the position of the Observer on the Earth's surface may be said to be definitely fixed. It is therefore, necessary to further identify the Latitude by the terms North and South and the Longitude by the terms East and West. The term plus is also used for North and minus for South.

Sea-Mile—The unit of linear measurement at sea is the mile. It is supposed to be one fifty-four hundredth of the distance at sea level from the equator to the Poles of the Earth. By this method it was attempted to make one minute of arc and a sea-mile the same and for all practical purposes such is the case. It is equal to 6080.27 feet and for distances within ten miles on the Earth's surface 2000 yards is quite frequently used.
When travelling along the Equator one minute of Longitude and one sea-mile are equal to each other but we will change our Longitude more than one minute of arc for a sea-mile of Easting or Westing any where else on the Earth's surface. Assuming the Earth to be a sphere, the number of minutes change of Longitude equals the number of sea-miles of Easting or Westing times the Secant of the Latitude at any parallel of Latitude.

Dead Reckoning—Let us assume that we leave a point of reference A whose Latitude and Longitude are definitely known or obtainable, and that we go C_1 miles in direction Z_1 degrees measured from the True Meridian, C_2 miles in the direction Z_2 degrees with the True Meridian, etc., the process of determining the Latitude and Longitude arrived at is called Dead Reckoning. The angles Z are known as Courses and we will see later there are three kinds, Compass, Magnetic, and True, but in Dead Reckoning all Courses are reduced to True Courses. Dead Reckoning is abbreviated by the letters D. R.

TABLE 2 BOWDITCH

Table 2 Bowditch is a traverse table adapted to Navigation purposes. It may be used to solve any right-angled plane triangle encountered in Navigation work.

At the top and bottom of the pages are given angles in degrees which correspond with Course Angles made with the True Meridian. There are four angles given, the additional three in parenthesis are for use with a compass graduated from 0° to 360°. The angle outside of the parenthesis indicates the size of the angle measured from either the North or South point of the True Meridian, the 2nd angle is the value of the 1st. angle if South and East measured from the North point of the True Meridian, the 3rd angle is the value of the first angle if South and West measured to the right from the North point of the True Meridian, and the 3rd angle is the value of the 1st. angle if North and West measured to the right from the North point of the True Meridian. It is suggested before you go further in this book that you take your Bowditch and mark over the first angle the letters NE, the second angle the letters SE, the third angle the letters SW and over the fourth angle NW. By so doing you will save yourself much time and trouble in identifying Course from Easting and Westing or Northing and Southing, etc.
Under column marked Dist are numbers which represent distances or the hypothenuse of the right-angled triangle from 1-600, but for the same angle if we multiply Dist, Lat, and Dep, by the same number the relationship holds good therefore we can use the tables for any numbers encountered in Practical Navigation. The figures in Lat column are obtained by multiplying the corresponding number in the Dist column by the cosine of the angle, and the figures in the Dep column by multiplying the number in the corresponding Dist column by the sine of the angle. In view of the fact that the Sin A = Cos (90°-A) and Cos A = Sin (90°-A) the tables need not be constructed for angles in excess of 45°, for by subtracting the angle at the top of the page from 90° and marking the Lat column at the top of the page Dep at the bottom, and marking Dep column at the top of the page Lat at the bottom, we have the table complete for all angles from 1-90°. Of course if the angle is 0° then Dist and Lat are the same and Dep is zero and if the angle is 90° then Dist and Dep are the same and Lat is zero.

Longitude and Departure—Since Lat is Dist times the cosine of the angle, if we desire the minutes change in Longitude corresponding to any given Departure, by turning to the page which has an angle equal to the Latitude and pick out Dist corresponding to a number in the Lat column equal to the given Departure, this number picked out from the Dist column will be the corresponding minutes of Longitude. If Departure corresponding to any given change in Longitude is desired, reduce the Longitude to minutes and tenths of minutes of arc, turn to the table which has angle equal to the Latitude and from the Lat column pick out the number corresponding to a number in the Dist column equal to the minutes of change of Longitude, this number picked out is the Departure desired.

Memorize the following:

(1) Using angle at the bottom of the page pick out Lat and Dep from the columns marked Lat and Dep at the bottom of the page.

(2) Course angle at the top of the page Lat is greater than Dep and the course angle is not greater than 45°.

(3) Course angle at the bottom of the page Dep is greater than Lat and the Course angle is not less than 45°.

(4) We may shift the decimal point at will the same number of places in Dist, Lat, and Dep without disturbing the relationship between them for any given angle.

(5) Lat greater than Dep the Course angle will be found at the top of the page, the greater the difference the nearer to 1°.

(6) Dep greater than Lat the course angle will be found at the bottom of the page and the greater the difference the nearer to 89°.

(7) After the nearest coincidence of Lat and Dep have been obtained in interpolating for Dist use the greater of the two for interpolating.

It is very essential that you realize the above precepts in order to do justice to Table 2 Bowditch.

Dead Reckoning by Traverse Tables Necessary—Some Navigator may tell you that Dead Reckoning by Traverse Tables is a lost art, do not accept it. It is much easier and simpler to even move Lines of Position by Traverse Tables, than to move them on a chart, they are both good checks on each other and the Wise Navigator, that is the fellow who gets caught in the fewest mistakes, uses both methods.

I once knew an officer who as Navigator, for a very short period, that nearly hit the Farallones eight or ten hours ahead of time, because he made a mistake of a few degrees in transferring a D. R. position from one chart to another.

EXAMPLE

The angle with the Meridian or True Course is 54° and Distance 58.4 miles find the Lat and Dep by Table 2 Bowditch.

We first note in accordance with our rules that as the Course Angle is Greater than 45° we will find it at the bottom of the page. We could of course look for Dist 58 and then for 59 and interpolate between them but as the three figures 584 are less than 600, the easiest way is to pick out Lat and Dep for 584 and divide them by ten. Remember you are on the bottom of the page so look out for getting the right Lat and Dep columns.

Dist.	Lat.	Dep.
584	343.2	472.5
58.4	34.32	47.25

EXAMPLE

The angle with the Meridian or True Course is 24° and Distance 61.5 miles find the Lat and Dep by Table 2 Bowditch.

The Course Angle less than 45° therefore will be found at the top of the page. The combination 615 is greater than 600 therefore we may interpolate between 61 and 62.

Dist		Lat		Dep
62		56.6		25.2
61		55.7		24.8
1		.9		.4
.5	.5 x .9 =	.45	.5 x .4 =	.2
61.0		55.7		24.8
61.5		56.15		25.0

The above work is done as a problem in mental arithmetic but if you are going to use pencil and paper which is perfectly legitimate in Practical Navigation it might be better to do as follows:

Dist	Lat	Dep
.5	.46	.2
61.0	55.70	24.8
61.5	56.16	25.0

We pick out Lat and Dep and put decimal points in front of them making the Dist .5, Lat .46, and Dep .2, in other words we make the table do its own interpolating.

EXAMPLE

Find the Course Angle and Distance for Lat 18.47 and Dep 38.57.

Dep is greater than Lat therefore the Course Angle is at the bottom of the page Table 2 Bowditch, and since both have two digits as whole numbers probably nearer 45° than 90°. We first try fitting the whole numbers first that is 18 and 38 and find under 50° Lat 32 and Dep 38; under 55° Lat 27 and Dep 38.5; under 60° Lat 22 and Dep 38.1; under 65° Lat 17.7 and Dep 38.1; therefore since 18.47 is between 17.7 and 22.0 we have narrowed the angle down to between 60° and 65° and since 18.47 is nearer 17.7 than 22 nearer 65° than 60°. Under angle 64° we find Lat 18.8 and Dep 38.6 and under 65° Dep 386 and Lat 180 dividing by ten gives Lat 18.0 and Dep 38.6. Since 18.47 is nearer 18.8 than 18.0 we select 64° for the Course Angle. Taking the larger of the two the Dep 38.57 for interpolating we find in Dep column under 64° 385.6 and corresponding Dist 429 dividing by ten gives Dep 38.56 and Dist 42.9, we accordingly write our answer Course Angle 64° and Dist 42.9.

EXAMPLE

The change in minutes of Longitude is 1551 and the Latitude parallel is 62° what is the Dep or p?

Turn to angle 62° remembering that as it is greater than 45° it will be on the bottom of the page, and be careful to get the column marked Lat at the bottom of the page. Under distance 155 we find 72.8 multiplying by ten gives Dist 1550 and Lat 728 and opposite 1 in Dist is .5 in Lat therefore 1551 in Dist will give 728 plus .5 in Lat or 728.5. The Dep then corresponding to change in Longitude of 1551′ is 728.5 sea-miles.

EXAMPLE

The Dep or p is 838.65 and the Latitude 35° what is the corresponding change in Longitude?

Latitude less than 45° angle at the top of the page. For 83.6 in Lat column we find 102 in Dist column therefore 1020 will correspond to 836. 838.65 − 836 = 2.65, for 265.5 in Lat Column 324 is in Dist column therefore 2.65 will give 3.24 in Dist column. The final Dist corresponding to 838.65 is 1020 plus 3.2 or 1023.2 therefore the corresponding change in Longitude is 1023.2′ or dividing by 60 to reduce to degrees the answer is 17° 03.2′

PRACTICAL EXAMPLES

(8) Dist 432.8 Course Angle 28° find Lat and Dep.
(9) Dist 336.9 Course Angle 48° find Lat and Dep.
(10) Dist .6 Course Angle 85° find Lat and Dep.
(11) Change in Longitude 338.4′ Lat 37° find Dep.
(12) Dep 238.56 miles Lat 48° find the change in Longitude in degrees, minutes, and tenths of minutes of arc.

CHAPTER C

Table 42 Bowditch—Logarithms

Table 42 Bowditch is what is known as a five place logarithm table of numbers to the base ten.

It is a mathematical fact that numbers may be multiplied together by adding their logarithms and finding the number corresponding to the sum of the logarithms; also that division of numbers is performed by subtracting the logarithm of the divisor from the logarithm of the dividend and finding the corresponding number to the resulting logarithm.

Since Table 42 is a table in which ten is the base it is only necessary to be able to get what is called the mantissa of a logarithm, for in the base ten the characteristic or figures to the left of the decimal point in the logarithm is known from the number of digits to the left of the decimal point in the number whose logarithm is desired. For instance, the characteristic of a logarithm of a number, is always one less than the number of digits to the left of the decimal point, in the number whose logarithm is desired, when using logarithms in the base ten. The table therefore only gives the mantissa or part to the right of the decimal point in the logarithm. The mantissa 17114 for instance only indicates a certain sequence of figures which runs 1483000 etc., and we can add as many ciphers as we like and place the decimal point where we like but mantissa 17114 always indicates the numbers 1483 with ciphers prefixed or affixed according to the value of the characteristic.

Mantissa .17114 is the logarithm of 1.483 written log 1.483 and since by multiplying of dividing by a certain power of ten we can produce any number having a sequence 1483 either as a whole number or decimal fraction, and as the log 10 to the base ten is 1 we deduce the following rules for logarithms of numbers:—

(1) Determine the mantissa of the sequence of digits from the logarithm table and put a decimal point in front of or to the left of it.

(2) Put in the characteristic to the left of the decimal point, its value being determined by subtracting one from the number of digits to the left of the decimal point in the number whose logarithm is desired.

(3) Should the number have no digits to the left of the decimal point as in the case of logarithms of decimal fractions, subtract the number of zeros immediately to the right of the decimal point from nine for the value of the characteristic and write minus ten after the logarithm. In case their are no zeros immediately to the right of the decimal point in the number, then zero from nine leaves nine and the characteristic is nine with minus ten written after the logarithm.

Use of the Table—It should be noted that the left hand column contains numbers with three digits and has the abbreviation "No" for number over it, and that columns with five digits in them numbered from 0-9 run across the page. These numbers in the 0-9 columns are the mantissas of logarithms of a sequence of numbers which have the three figures in "No" column for the first three digits, the number over the mantissa column for the fourth digit, for a number of five or more digits being found by interpolating.

The mantissa of the first four digits is subtracted from the mantissa of a number having a digit in the fourth place one greater; then look in the columns to the right of the mantissa columns for one headed by this difference in mantissas in black type, and running down the column pick out the number corresponding to the value of the fifth digit on the same line with it, the digits being shown in a vertical line from 1-9. We then add this number to the lesser of the two mantissas previously picked out, the resulting mantissa is the mantissa of the number. The characteristic is found in accordance with rules 1-3 previously given.

A little more accurate way of doing it is to consider a decimal point between the fourth and fifth digit in the number, multiply the difference between the mantissas by the decimal fraction formed, and adding the result to the mantissa of the first four digits, in case the amount to be added has a decimal part

in it if the decimal part is .5 or greater the amount to be added is increased by one otherwise only the whole number part is added. Still another way of doing it is if the sixth digit is 5 or greater is to increase the fifth digit by one and use the tables to the right of the mantissa columns.

EXAMPLE

Find the logarithm of 1947632.

Since there are seven places to the left of the decimal we know at once that the characteristic will be seven minus one therefore six.

```
Mantissa 1948  = 28959
Mantissa 1947  = 28937
                 -----
                    22
                  .632
                 -----
                    44
                   66
                  132
                 -----
                13.904  = 14 to the nearest whole number
                          28937
                          -------
log 1947632 =             6.28951
```

In order to avoid the multiplication of 22 by .632 we could have looked over in the right hand column and picked out from the column headed by 22 and for digit 6 the number 13 which added to the mantissa 28937 gives 28950 and then written the log as 6.28950 as the answer. If our number had been .00001947632 the process would have been the same so far as mantissa is concerned, our characteristic would have been obtained by subtracting the four zeros to the right of the decimal point from nine giving five and the resulting log would have been 5.28951–10 or 5.29850–10 depending on which method you used. Either method is correct for Navigational purposes for we are concerned with Practical Navigation and not splitting hairs on results.

EXAMPLE

Find log .00068

Look up the mantissa for 680 which we find to be 83251 and since there are three zeros in our number three from nine leaves six therefore we write the log .00068 as 6.83251–10.

Square Root by Logarithms—We frequently have to take square root of a number in Navigation work as in the Time-Sight-formula for example. By logarithms it is quite quickly done, by finding the log of the number dividing the log by two, and finding the number corresponding to the resulting division. In finding the square root of a fraction we have to juggle the logarithm a bit in order to use the tables with base ten, as the resulting log must have minus ten after it.

EXAMPLE

Find the square root of .00068.

From the previous paragraph log .00068 = 6.83251–10 which divided by two equals 3.41626–5 which while a perfectly good log, since it has –5 after it, is not in shape for using the log table, as we must have –10 after it in order to use our rules for the characteristic. By adding five and subtracting five we make it 8.41626–10 in which shape we can find the number corresponding to it. The number corresponding to mantissa 41626 is 26077 therefore the square root of .00068 is .026077 as eight from nine leaves one therefore we place one cipher in front of the first digit of the sequence. The usual practice is to add enough tens and subtract the same number of tens before dividing by two, thus we would make the log .00068 = 16.83251 – 20 which is the same value as 6.83251 – 10 and dividing by two gives 8.41626 – 10.

In order that the Practical Navigator may become imbibed with the absolute necessity of checking himself and immediately sense a wrong result your attention is called to a quick check on the result. The square root of a decimal fraction is always less than one, is always greater than the fraction itself, and

contains one half as many places. In arithmetic we point off as follows .00-06-80 it thus becomes evident that the square root will run as follows: .02 etc. as the square root of 6 is 2 plus therefore when we see our answer by logarithms come out .026077 we may feel reasonably sure we are not far wrong and have made no mistake in our work. Let us suppose that we subtracted the three in 3.41626−5 from nine and have attempted to put six zeros in front of the sequence, our common sense should tell us something was wrong, this is not an imaginary supposition, for I have seen it done.

The Number Corresponding to the Logarithm—My first caution is remember that you do not want the log of the log but the number corresponding to the logarithm. The first step concerns the mantissa only, or the five figures to the right of the decimal point, in the positive part of the logarithm. For the time being consider these five figures a whole number, and look under the columns 0-9 for the nearest five figures just less than the five figures of the mantissa of the logarithm, subtract this nearest number just less than the mantissa from the nearest number just greater than the mantissa and also from the mantissa, the digits of the decimal fraction formed by the two results will give the fifth, sixth, etc., digits of the number corresponding to the log, the first three digits being the three figures in the "No" column on the same horizontal line with the five figures just less than the mantissa, and the fourth digit the number 0-9 heading the column, that has the five figures selected just less than the mantissa of the logarithm In order to avoid solving the fraction, look over in the right hand columns for a column headed by the difference between mantissa just less and just greater than your mantissa, and then run down the column until you come to the nearest number to the difference between the mantissa just less and the mantissa of the logarithm, the digit on the same line in the vertical column 1-9 will be the fifth digit of the number, the first three being the number in the "No" column and the fourth the digit 0-9 which heads the column containing the mantissa just less than the mantissa of the logarithm.

The value of the number is obtained from the characteristic as follows, no minus quantity after the log point off one greater place than the characteristic, that is the whole number will have one greater number of digits than the number of the characteristic, if there are not enough digits in sequence of numbers add enough ciphers to supply the deficiency. If the log is of a fraction, that is has a minus quantity after it subtract the characteristic from nine and prefix that number of ciphers to the sequence of numbers obtained from the table corresponding to the mantissa, this assumes that the minus quantity is minus ten.

EXAMPLE

Find the number corresponding to 4.09420.

Mantissa		No
09412	09412	1242
09420	09447	1243
8	35	1

35)8.0(.22857
70
100
70
300
280
200
175
250
245

therefore the number corresponding to 4.09420 is 12422.2857.

In using the right hand columns for interpolating the column headed by 35 shows digit opposite to 7 the nearest to 8 in the column as 2, therefore the number runs 12422, but as the characteristic is for five whole numbers, it would usually be further interpolated by subtracting 7 from 8 and also from 11, and write the fraction as $\frac{1}{4}$ thus getting 12422.25. It would have been accepted as correct in most Navigation work as 12422.

PRACTICAL EXAMPLES

(13) Find the log 1551.
(14) Find the log 18.7638.
(15) Find the log .00783972.
(16) Find the square root of 18.7638.
(17) Find the square root of .00783972 by logarithms.
(18) Find the number whose log is 8.95472.
(19) Find the number whose log is 8.95472−10.
(20) Find the number whose log is 6.38976−20.

CHAPTER D.

Table 44 Bowditch—Logarithms

Table 44 Bowditch is a five place logarithm table to the base ten of the following functions of angles,—sine, cosine, tangent, cotangent, secant, and cosecant. In this table the characteristic and mantissa are both given and it should be borne in mind that MINUS 10 is to be written after each logarithm.

Like Table 2 as the sin A = cos (90°-A), cos A = sin (90°-A), tan A = cot (90°-A), cot A = tan (90°-A), sec A = cosec (90°-A), and cosec A = sec (90°-A), the table need not be constructed for angles except between 0° and 45°.

We can mark the function at the top of the page, its opposite or co-function at the bottom of the page, and the angle at the bottom 90° minus the angle at the top of the page. The table gives the logaritmic function to the nearest minute of arc, the logarithmic functions to seconds of arc being found by interpolating. The left and right hand columns have whole number of degrees top and bottom over the column headed by M, the numbers in the M columns on the left hand side running from 0 − 60 from the top, and the right hand column beginning with 0 and running to 60 at the top. These numbers are minutes of arc.

Function of an Angle 0° − 45°—In order to find the log function of an angle between 0° − 45°, we look for an angle at the top of the page, left hand over M column, corresponding to the whole number of degrees of the angle. Run down the left hand M column until you come to a number equal to the minutes of your angle, then run across horizontally to the column marked at the top the function you desire. Reduce your seconds to a decimal part of a minute, multiply it by the difference between the value of the log function corresponding to our minutes of arc and an angle one minute greater, add or subtract it from the value of the function obtained for the angle having the degrees and minutes of your angle, according as the same function for an angle one minute greater is greater or less.

EXAMPLE

Find the log sin, log cos, log tan, of 18° 25′ 33″.

	Sin	Cos	Tan	
18° 26′	9.49996 − 10	9.97713 − 10	9.52284 − 10	60)33(.55
18° 25′	9.49958 − 10	9.97717 − 10	9.52242 − 10	30
1′	.38	4	42	30
	.55	.55	.55	30
	1.90	.20	2.10	
	19.0	2.0	21.0	
	20.9	− 2.2	23.1	
	9.49958 − 10	9.97717 − 10	9.52242 − 10	
	9.49979 − 10	9.97715 − 10	9.52265 − 10	

It is very important to watch whether the log function of the angle one minute greater, is greater or less than the function of the angle having the same number of minutes and no seconds, then you know at once whether to add or subtract in interpolating. In order to save the work of multiplying by the decimal part of a minute since there are sixty seconds in a minute, you will find a column marked "Diff" beginning with 0 at the top corresponding to the 0 in the left hand minute column (M). In the left hand M column we run down the column to 33 the same number as our seconds and read off on the same horizontal line in Diff column corresponding to the log function desired as follows, under sin the number 21, under cos the number 2, and under tan the number 23. These numbers will be added or subtracted according as the function one minute greater is increasing or decreasing in value. Remember when getting the

amount to be added or subtracted for the seconds of arc always use the left hand column (M) whether your angle is at the top or bottom of the page.

For angles less than 5° or 84°–90° the Diff column is headed diff 1′ therefore you have to use the first method given by multiplying the Diff 1′ by the seconds of arc reduced to a decimal part of a minute.

Arrangement of Reciprocal Functions in the Table—The heavy vertical lines should be noted, and that the functions which are the reciprocal of each other are next to each other. Since the log 1 in any base is zero, the sum of the logarithms of the reciprocal functions are always equal to zero, therefore the values in the Diff column for the sine will be the same as for the cosecant, for the tangent the same as the cotangent, and for the cosine the same as for the secant. By arranging the table with the Diff column between the reciprocal function columns space is economized and the tables are handier to use.

Function of Angles 45°—90°—For angles between 45° and 90° use the bottom of the page looking for the value in whole degrees under right hand M Column. For minutes use the right hand column reading 0–60 from the bottom up. Do not fail to get the function column as marked at the bottom, be careful about it at first because you may have a tendency to use the function columns as marked at the top which will be entirely wrong when the angle is at the bottom of the page. Convert the seconds into the decimal part of a minute and multiply the difference in function for one minute by the decimal and add or subtract to the function desired for degrees and minutes according as the function is increasing or decreasing for an increase of angle of one minute.

After you have learned the method above given you may adopt the following which is the usual way of doing it. Pick out the log function for the degrees and minutes as before, run down the left hand M column until you come to a number equal to the seconds, run horizontally across the page until you get to Diff column corresponding to the log function desired, and add or subtract, the value to the function for the degrees and minutes of the angle, according as the function is increasing or decreasing for an increase of 1′ angle.

EXAMPLE

Find the log sin, log cos, log cot, of 71° 34′ 27″.

	Log Sin	Log Cos	Log Cot
71° 35′	9.97717–10	9.49958–10	9.52242–10
71° 34′	9.97713–10	9.49996–10	9.52284–10
1′	4	– 38	– 42
	.45	.45	.45
	20	190	210
	16	152	168
	1.8	– 17.1	– 18.9
	9.97713	9.49996	9.52284
71° 34′ 27″	9.97715–10	9.49979–10	9.52265–10

It should be noted that the amount added or subtracted is the nearest whole number in the fifth decimal place 1.8 being called 2, 17.1 is called 17, and 18.9 is called 19.

In using the Diff column, whether your angle is at the top or the bottom of the page, in interpolating for seconds, always use the left hand M column, and read seconds from the top down.

Reading from the top down left hand M column on the page where the bottom right hand angle is 71°, we find corresponding to 27, the number equal to our seconds of arc, under the column marked sin at the bottom of the page 2, under column marked cos at the bottom of the page 17, and under the column marked tan at the bottom of the page 19, which saves the decimal multiplication and is the usual way of doing it. If the angle is between 84°—90° you will have to convert the seconds to a decimal part of a minute, and multiply it by the Diff 1′ to get the amount to add or subtract, adding if the log function is increasing with increase of angle, and subtracting if the log function is decreasing with increase of angle.

Functions of Angles Greater than 90°—In this case subtract 90° from the angle and find the opposite or co-function of the resulting angle. When the Polar Distance is greater than 90° and you want its cosecant subtract 90° from it and find the secant of the resulting angle.

You will find at the right hand top and left hand bottom an angle greater than 90°. My advice to you is to take your pen and ink them out for fear you may be tempted to use them. A practical Navigator has no need for using the method their use implies. You will never have any use for the right hand top angle, and it is much easier and simpler to subtract 90° from your angle and find the co-function than to attempt to use the left hand bottom angle.

Function		Co or Opposite Function	
Sine	(sin)	Cosine	(cos)
Cosine	(cos)	Sine	(sin)
Tangent	(tan)	Cotangent	(cot)
Secant	(sec)	Cosecant	(cosec)
Cosecant	(cosec)	Secant	(sec)

Hour A. M. and Hour P. M. Columns—In the Time-Sight formula the hour angle t is found from the value of the logarithmic sine of one-half the hour angle t.

In order to avoid the necessity of finding one-half the angle t multiplying by two and then converting into hours, minutes, and seconds of time, the value of twice the angle whose sine is on the same horizontal line with it, is given on the same horizontal line in the P. M. column converted into hours, minutes, and seconds of time. Since for A. M. the time by clock will be the angle subtracted from twelve, the A. M. column is twelve hours minus the value in the P. M. column on the same horizontal line. The A. M. column then is only of practical value in observations of the Sun. In the observation of a planet, star, or Moon use only the P. M. column marking it minus when the body is East of the Meridian and plus when West of the Meridian. Remember that if your function is at the bottom of the page your P. M. column is the one marked P. M. at the bottom of the page.

The columns sine and cosecant at the top of the page, and cosine and secant at the bottom of the page, have the large letter A over and under them; secant and cosine at the top, and cosecant and sine at the bottom, have the large letter C over and under them; and tangent and cotangent top and bottom have the large letter B over and under them; these large letters indicate which horizontal line to use at the bottom of the page in interpolating for seconds of time. You will probably never have any use for the B line, very seldom the C, but the A line you will use often if you adopt the so called eight o'clock Navigation.

To find the Hour Angle whose logarithmic sine of one-half the angle is given, find the nearest value of the log sin less than the value given and note the difference between them, then on the line with A, sometimes C when the H. A. is greater than six hours, you pick out the seconds corresponding in the vertical column; the practice being to interpolate for tenths of seconds. It is very important to note whether the time is increasing or decreasing for increase in hour angle, for if increasing you add the seconds from the A or C column and if decreasing you subtract. In working out a Sun Sight pick out from the A. M. or P. M. column according as the observation is taken before noon or afternoon.

EXAMPLE

Find t, P. M. and A. M. in hours, minutes, and seconds, log sin $\frac{1}{2}$ t = 9.52890.

The nearest value in the tables less than 9.52890 in the sine column is 9.52881 and the problem may be set down and worked out as follows:

A. M.	P. M.	Log Sin		
9—21—52	2—38—08	9.52916	log sin ½ t	9.52890
9—22—00	2—38—00	9.52881		9.52881
— 08	08	35		35)9.00(.26
.26	.26			7 0
2.08	2.08			200
9—22—00	2—38—00			210
9—21—57.9	2—38—02.1			

Under 9 in Prop. parts of cols. line A the seconds given in the vertical column are two and since for increasing value of the sine, P. M. values are increasing and A. M. values decreasing, we could have added 2 s to 2 h 38 m 00 s and subtracted 2 s from 9 h 22 m 00 s and the results would have been 2 h 38 m 02 s p. m. and 9 h 21 m 58 s a. m.

PRACTICAL EXAMPLES

Find:

(21) log sin 27° 38′ 15″ (22) log sin 63° 15′ 33″
(23) log cos 79° 33′ 12″ (24) log sec 15° 27′ 15″
(25) log cosec 115° 10′ 30″ (26) log tan 38° 10′ 15″
(27) log cot 67° 19′ 47″

Find A. M. and P. M. hour angles:

(28) log sin ½ t = 9.52610 (29) log sin ½ t = 9.89690
(30) log sin ½ t = 9.78912

Find by logarithms:

(31) 432.8 sin 28° (32) 336.9 sin 48°
(33) 338.4 cos 37° (34) 238.56 sec 48°

In practical working of problems in Navigation there will be no necessity for writing minus ten after the functions of the angles, for characteristic 6—9 we know is log of a number less than one, and characteristic 10—13 is a logarithm of a number greater than one, it is therefore usual to leave off the minus ten after the logarithms characteristic 6—9 and those having characteristic 10—13 to subtract the minus ten before writing it down changing the characteristic as given in the table 10—13 to 0—3 except that the zero is not written—for instance the log cot 1° would not be written as given in the table 11.75808 with an understood minus ten after it but would be written 1.75808.

CHAPTER E

Compass

Mariner's Compass (Magnetic)—The Mariner's Compass is a magnetic instrument used byMariner's to indicate the direction of the ship with respect to the Compass North and South line. The magnetic needle has the property of pointing always in a Northerly and Southerly direction when unaffected by local masses of iron or other magnetic bodies. The instrument is a very old and ancient one.

"The Chinese Annals assign the discovery to the year 2634 B. C., when they say an instrument for indicating the South was constructed by the Emperior Ho-ang-ti and it was used exclusively for guidance in travelling by land, but we hear of their using it by sea only somewhere about 330 A. D. (Chambers Encyclopedia)."

As at present constructed the compass for Mariner's consists of a number of magnetic needles bound or held together, the magnetic axes being parallel. They are of two general types the wet and dry compass. The U. S. Navy uses the wet type although the dry type is perhaps more prevalent in the Merchant Marine. They both have their advantages and disadvantages and are well made reliable instruments.

Compass Gyro—The Gyro compass is an electro-mechanical instrument designed to give the direction of true North and South, being graduated in degrees from 0–360, the zero representing North. It being an installation, that is consisting of a number of electro-mechanical instruments, the cost of using it practically prohibits its use for Navigational purposes alone, even if the first cost itself did not make it prohibitive. It is certainly a beautiful installation for piloting; but up to the year 1918 at least, it was an unreliable instrument in any but smooth weather, and always had to be checked with a magnetic instrument. It is not my intention to condemn the gyro-compass, for it has been too good a friend of mine and is a wonderful installation in piloting and in smooth weather, but up to 1918 the mechanical correction for preventing occillations being set up in the gyro due to rolling and pitching just did not do the job. Even should the installation become perfected its cost of installation and operation renders its general use prohibitive, you will always have to have the magnetic instrument to check it in case something goes wrong with the gryo.

It is used in exactly the same way as the magnetic compass, its error determined and marked the same, the repeater dials are graduated the same as the magnetic compass card, so if you understand the use of the magnetic compass you will have no difficulty with the gyro.
Even if you have the gyro do not neglect your magnetic compass, keep it in adjustment and its deviation up to date. There is little excuse for even the magnetic compass in the steering engine room of a battleship being out of adjustment, with a gyro installation to adjust it at any time when the gyro is known to be working O. K.

Variation—The Magnetic Meridian or the direction in which the compass needle points when constrained to move only in the horizontal plane, does not coincide with the direction of True North; this angular difference between the True North or True Meridian is called the Variation of the compass, provided the needle is not acted upon by forces within the ship or other local force. The angle is marked East or Plus, when the Magnetic Meridian is to the East or right of the True Meridian, and West or Minus when the Magnetic Meridian is to the West or left of the True Meridian.

Deviation—Due to the various forces of magnetism existing in steel or iron ships, the Compass Meridian or actual angle between North by Compass on a ship and the keel line on any heading, does not represent the angle between the keel line and the Magnetic North, this deviation from the magnetic angle as the ship moves around the Compass is called the Deviation on that heading by Compass. It is different for different headings when the compass is uncompensated. It is measured by the angle between Magnetic North and North by Compass on any Heading by Compass and is marked similar to Variation. When North by Compass is to the East or right of Magnetic North, Deviation is marked East or Plus; when North by Compass is to the West or left of Magnetic North, deviation is marked West or Minus.

The location of the Standard Compass on board steel ships has to be carefully considered, especially its location relative to vertical soft iron. Very high deviations have been recorded in the case of uncompensated compasses on steel ships, almost to complete reversal of direction of the needle. The most dangerous condition here is not so much the deviation itself which is bad enough, but the needle becomes sluggish or inactive on some headings and quick and violent on others, therefore a compass with large deviations is dangerous to the safety of the ship, for even if the deviation has been obtained the compass is still unreliable, as its directive force is not constant but extremely variable and unreliable. For armored ships deviations up to 9° 00′ may be considered passable if due to change in Magnetic Latitude, but it should be reduced to less than 3° 00′ at the first opportunity. For a Merchant Ship to carry 9° 00′ of Deviation in her Standard or Navigating Compass jeopardizes the safety of the vessel, as it is seldom justified even in wide changes in Magnetic Latitude or by the character of the cargo.

Course—The Course of a ship is the angle between the keel line and the Meridian, maintained by the ship in its passage through the water. As there are three kinds of Meridians if follows there are three kinds of courses,—True Course or angle between the keel line and the True Meridian, or North True; Magnetic Course or angle between the keel line and Magnetic Meridian or North Magnetic; and Compass Course or angle between the keel line and Compass North.

The difference between the True Course and the Magnetic Course is the Variation of the Compass; the difference between the Magnetic Course and the Compass Course is the Deviation of the Compass on the compass Course; and the Difference between the True Course and the Compass Course is the Compass Error on the Compass Course.

Leeway—Leeway is a term used to denote the set of the ship due to side pressure of the wind on the sails in sailing vessels, when sailing more or less Close Hauled. It is an estimate of the difference in angle between the Course being made good by Compass and the Compass Course, and is almost invariably expressed in points or fractions of points of the compass.

Leeway has always been a thing whose existence in the case of sailing vessels is indisputable but whose value is more or less indeterminate. It is considered as so much additional compass error to be applied to the Compass Course to get the True Course, if the wind is on the starboard side mark leeway West or minus, if the wind is on the port side mark leeway East or Plus and use it just like Variation and Deviation.

In sailing vessels there was some foundation for its use, for the speed of the ship was obtained by Heaving the Log, the speed being practically measured along the line made good, and the drift to leeward and the ship's speed through the water were caused by the same force. It is unfortunate that the Department of Commerce requires you to use it to get your license for that is the only practical use you will ever have for it in power-driven vessels, it is simply absurd to attempt to get any practical results from its use in power-driven vessels as so many points displacement of the Compass Course. No Practical Navigator is going to ball up his Dead Reckoning with Leeway in power-driven vessels. We will show you the method so you will be able to get your license from the Department of Commerce.

Rule for Variation—Consider yourself at the center of the compass, if the Variation is East or Plus apply it to the right of the Magnetic Course to get the True Course, and if the Variation is West or Minus apply the Variation to the left of the Magnetic Course to get the True Course. If you are working from True to Magnetic Courses remember you do the opposite, so many mistakes are made in going from True to Magnetic and Compass Courses.

Rule for Deviation—Consider yourself at the center of the Compass, if the Deviation is East or Plus apply the Deviation to the right of the Compass Course to get the Magnetic Course, if the Deviation is West of Minus apply the deviation to the left of the Compass Course to get the Magnetic Course.

Rule for Compass Error—Add the sum of the Variation and Deviation in accordance with their signs or letter and if there is leeway given add it in too. This sum is known as the Compass Error without leeway and when Leeway is used it may be called Total Error for want of a better name. Considering yourself in the center of the Compass you apply it to the right of the Compass Course if East or Plus, and to the left of the Compass Course if West or Minus, to get the True Course.

In working from a True Course to a Compass Course remember you do exactly opposite, be very careful at first as you will make many mistakes, and if you do a catastrophe may result. Never be ashamed to have someone check your courses for you.

Compass Course	N 60° E	S 60° E	N 60° W	S 60° W
Compass Error	18° 15′W	18° 15′W	18° 15′W	18° 15′W
True Course	N 41° 45′E	S 78° 15′E	N 78° 15′W	S 41° 45′W
Compass Error	18° 15′W	18° 15′W	18° 15′W	18° 15′W
Compass Course	N 60° 00′E	S 60° 00′E	N 60° 00′W	S 60° 00′W
True Course	N 41° 45′E	S 78° 15′E	N 78° 15′W	S 41° 45′W
Compass Error	18° 15′W	18° 15′W	18° 15′W	18° 15′W
WRONG COURSE	N 23° 30′E	N 83° 30′E	S 83° 30′W	S 23° 30′W

A comparison of the correct compass course, and the wrong compass courses, shows conclusively what can and will happen if the compass error is applied the wrong way. This is not a case that may be accepted in Navigating Work as a mistake after you have given the Compass Course to the officer of the watch or the Captain of the Ship, it then becomes a case of incompetency.

Do not be ashamed to have somebody check your courses, teach your Quartermaster how to do it, or have some other officer check it for you. Except under dire necessity never set a compass course until you have had somebody check it independently, always be right yourself, but you are going to find that you are human, therefore will make mistakes.

PRACTICAL EXAMPLES

(35) Compass Course N 55° W, Dev. 1° 15′ W, Var. 6° 00′ W, find the Magnetic Course, and the True Course.

(36) Compass Course S 38,° E, Dev. 1° 15′ E, Var. 11° 30′ W, find the True Course.

(37) True Course S 20° E, Var. 18° 15′ E, Dev. 2° 25′ W, find the Magnetic Course and the Compass Course.

In the majority of Merchant Ship Compasses, compass cards are graduated 0° at the North and South points of the compass and graduated in degrees up to ninety to the East and West; hence the marking North so many degrees East and West, and South so many degrees East and West.

Whenever you get a problem given in points convert into degrees preferably from 0-360 degrees, unles it is a problem in distance off by run and two bearings when you use Table 5A Bowditch.

Note:—See photograph page 15 Bowditch and the tables page 16 Bowditch.

CHAPTER 1

McCracken Form 1

Dead Reckoning—Distance Off (5A Bowditch)—Set and Drift.

Dead Reckoning—Let us assume, that we leave a point of reference A whose Latitude and Longitude are definitely known or obtainable, that we go C_1 miles in direction Z_1 degrees measured from the Meridian, C_2 miles in the direction Z_2 degrees with the Meridian, etc., the process of determining the Longitude and Latitude arrived at is called Dead Reckoning abbreviated D. R.

The angles Z are known as courses and they are of three kinds—Compass Courses, Magnetic Courses, and True Courses, they are always reduced to True Courses in the process of Dead Reckoning. The point of reference A is known as the Point of Departure.

Point of Departure—Points of Departure are rather varied in their type, but the essential feature of a point of departure is that it must be an observable position and its Latitude and Longitude known or obtainable. Points of Departure may be Light Houses, Prominent Landmarks on charts of a well surveyed locality, Light Vessels, Buoys, Astronomical Positions, Radio Position Fixes, Well Defined Banks or Shoals limited in area. In using other than Light Houses and Prominent Landmarks on charts of a well surveyed locality as points of departure caution should be observed in approaching land or shoal water.

Light Vessels off shore and Buoys drift and drag besides they are not always placed with extreme accuracy. Good Astronomical Positions should be assumed in error three miles; Radio Position Fixes unless you can see any probable danger should not be relied on as a fix unless confirmed by other data or observation, remember you are dependent upon someone else for the accuracy of your position, whereas the law of the sea requires the Navigator to take personal responsiblity for the position and safety of his vessel; and while the use of banks and shoals can be made use of by experts on Navigating in a vertical plane who possess the local knowledge, if you get hold of a bank or shoal water in making port in a fog do not forget that you should have two perfectly good anchors ready for use and use one of them.

Position at Departure—Due to the depth of water and the fact that two separate bodies may not occupy the same spot at the same time, the Position of the Ship at Departure seldom coincides with the Point of Departure. It is therefore necessary to establish "The Position at Departure." This may be done by Cross Bearings, by a combination of bearing and distance, by simultaneous distances from two fixed objects, and by angular measurement as in the case of Astronomical Positions.

Cross Bearings—The method of Cross Bearings is the taking of simultaneous bearings by compass of two or more fixed objects, reducing the bearings to True or Magnetic, and drawing lines of Position on a chart from the objects on the True or Magnetic Bearings, the intersection of the lines giving the position of the observer. This method is generally conceded as the most reliable method of fixing the position of a vessel underway, but its accuracy is dependent on the accuracy of the Compass Deviation and Compass Error.

Bearing and Distance—In this method a Bearing of a fixed object is taken when the distance may be directly obtainable as by range finder or sextant angle, or indirectly obtainable by calculation based on the speed of the vessel. The method based on the speed of the vessel is the one more generally used except on vessels having a good range finder. In the sextant or vertical angle method the vertical angle of the height of the object to the surface of the water is taken and by looking up the vertical height of the object from a light list or chart and using Table 33 Bowditch the distance off may be obtained.

Distance Off (5A and 5B Bowditch)—In this method a bearing is taken of the fixed object and the ship kept on a steady course. After a certain change of bearing angle has taken place, from the speed of the ship or distance travelled in the interval between bearings, the distance off at the second bearing and the distance passed or to be passed abeam may be calculated. Table 5A Bowditch is the one more

nerally used but 5B may be used when bearings are taken in degrees. The bow and beam bearing, ubling the angle on the bow, etc., may all be solved by Tables 5A and 5B.

EXAMPLE

mpass Bearing of a Light House NW½N, Compass Course N by W ½ W p. log 18.5, second compass aring WNW ½ W p. log 22.6, required the distance off at the second bearing and distance to be ssed abeam.

log 22.6 – p. log 18.5 = 4.1 miles distance run

		Pts. from N	Diff.	Multiplier		Distance	
						Off	Abeam
urse	N by W ½ W	30 ½					
Bearing	NW ½ N	28 ½	2				
d Bearing	WNW ½ W	25 ½	5	.69	.57	2.8	2.3
				4.1	4.1		
				69	57		
				2.76	2.28		
				2.829	2.337		

e distance off then is 2.8 miles and the distance to be passed abeam 2.3 miles.

mpass Bearing of a Light Vessel ENE ½ E watch time 8–26–30 compass course NW ½ W estimated ed of ship 12 knots. At 9–27–30 compass bearing ESE ½ E. Required the distance off at the second aring and distance passed abeam.

T. 9–27–30
T. 8–26–30

T 1–01–00 × 12 knots = 12.2 miles distance Run.

		Pts. from N	Diff.	Multiplier		Distance	
						Off	Abeam
urse	NW ½ W	27 ½					
Bearing	ENE ½ E	6 ½	11				
l Bearing	ESE ½ E	9 ½	14	1.5	.57	18.3	6.954
				12.2	12.2		
				6.10	.854		
				12 2	6.10		
				18.3	6.954		

e distance off then at the second bearing is 18.3 miles and the distance passed abeam 7.0 miles (6.954).

McCracken Form 1—This form covers Dead Reckoning, Set and Drift by use of Table 2 Bowditch d Distance off by Table 5A or 5B Bowditch. Put in after Lat. Dep. and Long. Dep. the Latitude and ngitude of the Point of Departure. Use as a first course the reverse of the 2nd bearing and as distance e Distance Off at the 2nd bearing if departure was taken from a fixed object. Do not apply leeway to e reverse of the bearings used as a compass course but correct for variation and deviation only using e deviation for the ship's heading or course when the bearing was taken. In column 1 put in direction the wind, remembering that when departure is taken and the reverse of a bearing is used as a course not fill in wind column or leeway for that course. In the 2nd column put in the compass courses in grees preferably from 0° to 360°; fill in leeway column if leeway is given marking leeway East or plus wind is on the PORT side and West or minus if the wind is on the STARBOARD side. Fill in Devian and Variation columns being careful to put in plus or minus and East or West as the case may be. mbine leeway, deviation, and variation in accordance with their signs or letters and put the result in Error column being careful to put the sign or letter with it and then apply the Error to the Compass

Course in degrees as follows —if Plus or East apply to the right of the Compass Course, if West or minus apply to the left of the compass course to get the True Course. Fill in the distance columns to the nearest tenth of a mile. By the use of table 2 Bowditch put in the Difference in Latitude and the p or Dep. corresponding to the various True Courses and Distances being careful to get them in the proper column North, South, East or West as the case may be. Add up the N,S,E, and W columns. From the N and S columns subtract the smaller from the greater which will give the net or final change in Latitude and takes the name of the greater of the two columns N and S, apply this to the latitude of Departure which gives the Lat. by Dead Reckoning or Latitude IN. The difference between the Eastings and Westings being in miles must first be converted into minutes of Longitude which is done by use of Table 2 Bowditch using the Middle Latitude as the angle and the Difference between the Easting and Westing as Lat. and finding the corresponding Dist gives the minutes change of Longitude, which applied to the Longitude of Departure gives longitude by D. R. or Longitude IN. Be sure to always mark Latitude North or South and Longitude East or West as the case may be, then you need only remember to add like letters and subtract unlike.

In passing from Latitude of one name into Latitude of the other in crossing the Equator, and Longitude of one name into Longitude of the other in crossing the 0° Meridian, little difficulty will be experienced, but when crossing the 180th Meridian thumb rule Navigators frequently have trouble. In this latter case, you add the change in longitude to the Longitude left and subtract the total from 360° marking the result opposite in name to the Longitude left.

The following precepts may be of assistance:

(1) Difference of Latitude greater than Latitude left and of opposite name, you have crossed the Equator and the Latitude in or arrived at is the difference between the Diff. Lat. and the Latitude left and of opposite name to the Latitude left.

(2) Difference in Longitude greater than Longitude left and of opposite name, you have crossed 0° Meridian, and the Longitude in or arrived at, is the difference between the Diff. Long. and the Longitude left, and is opposite in name to the Longitude left.

(3) Difference in Longitude same name as the Longitude left and their sum greater than 180°, you have crossed the 180th Meridian, subtract their sum from 360°, and the result is the Longitude in or arrived at, and is of opposite name to the Longitude left. Remember that the Local Date will have to be juggled in this case.

Local Date Crossing 180th Meridian—(a) Crossing the 180th Meridian headed to the Eastward, keep the Local Date of the previous day, (b) Crossing the 180th Meridian headed to the Westward, add one day to the apparent Local Date, that is two days to the Local Date of the previous day.

Set and Drift—Fill in the Latitude and Longitude by Dead Reckoning at Local Apparent Noon and also the Latitude and Longitude by Observation at Local Apparent Noon. The difference in Latitude represents the drift in Latitude that is to the North or South as the case may be and the difference in Longitude the drift in Longitude to the East or West as the case may be. The direction of set is indicated by whether the Latitude by Observation is North or South of the Latitude by D. R., and whether the Longitude by Observation is East or West of the Longitude by D. R. Mark Diff. Lat. N or S and Diff. Long. E or W as the combination of the letters tells you how to mark your angle or which quadrant it is in. By Table 2 Bowdith reduce your Diff. Long. to p or Dep. by the Middle Lat. method, that is pick out number in Lat column corresponding to number in Dist column equal to the Diff. Long. and angle equal to the Latitude. With Diff. Lat. and p as arguments find their coincidence in Table 2 Bowd. the angle is the set and the number in the Dist column the Total Drift, which divided by the elapsed time since last departure, usually the Length of the Day, gives the drift in miles per hour, the time interval being reduced to hours and fraction thereof.

EXAMPLE

At 7:00 a. m. 26 January 1920 sighted The Pyramid, Fernando Normha, bearing NNW ½ W ship's head and Compass Course NE by E ½ E. After sailing 25 miles on NE by E ½ E Dev. 3° 15′ E, Var. 18° 30′ W, The Pyramid bore W ¾ S. Thence sailed as follows,—55.8 miles NE by E ½ E Dev. 3° 15′ E, Var.

18° 30′ W, wind N by W, leeway ½ point; 105.8 miles N by E ½ E, Dev. 2° 15′ E, Var. 17° 00′ W, wind South leeway 0 points; 120.7 miles NNW ¾ W, Dev. 1° 15′ W, Var. 16° 00′ W, wind NE leeway ¼ point. Required the Latitude and Longitude in or arrived at by D. R. and the distance The Pyramid was passed abeam. The position of The Pyramid is Lat. 3° 50.5′ S, Long. 32° 25.5′ W.

An observation position Lat. 0° 48.5′ N, Long. 33° 31.1′ W was obtained after sailing 20.8 miles NNW ¾ W wind NE, leeway ¼ point, Dev. 1° 15′ W, Var. 16° 00′ W, elapsed time since departure 55 h 04 m. Required the Set and Drift.

The above problem illustrates the use of McCracken Form 1 almost in its entirety. It is solved on appended form 1 to show its use and value.

Fill in the Latitude and Longitude of The Pyramid after Lat. Dep. and Long. Dep. The next step is to get the Distance Off at the second bearing and distance passed abeam. After Course in the part of the form for Distance Off write in the Compass Course steered between the first and second bearings. From page 16 Bowd. put in the points from North of the 1st and 2nd bearings, and then note the points from North of the Compass Course 5¼, which subtracted from 29½ the points from North of the first bearing gives a number greater than sixteen, The Pyramid was therefore on the port side, in which case we add 32 to the 5¼ making the points from North of the course 37¼ points. We can now subtract 29½ and 23¼ respectively from 37¼ which give 7¾ and 14 the Diff between the Course and the bearings. Turning to Table 5A Bowd. we look for 7¾ under the "Difference between the Course and the First Bearing in Points," running down the left hand vertical column to 14, and then horizontally across to the 7¾ column we find the multipliers 1.06 and .41: The first one is for the Distance Off at the second bearing and the second one is for obtaining the Distance Off when abeam. Since the Distance Off must always be greater than the distance abeam, except in the case where they are equal, as when the second bearing is taken when the object is abeam, the greater of the two multipliers must always apply to the Distance Off at the second bearing. Multiplying the Distance Run by the multipliers we get 26.5 miles as the Distance Off at the second bearing and 10.25 miles the distance passed abeam.

Should you look up the depth of water in the vicinity of Norhma, remember this problem is made up to illustrate the principle and method of doing Distance Off, etc.

Reverse the 2nd bearing which will give E ¾ N and convert into degrees and minutes in the 0°—360° method which gives 81° 34′ as the first course. Remember you use the Deviation for the Compass Course actually being steered at the time the bearings were taken. Combine the Deviation and Variation in accordance with their signs or letters getting the Error, which apply to the Compass Course thereby getting the True Course. With the True Course as the angle and the Dist. Off at the 2nd Bearing enter Table 2 Bowd. and fill in the Diff. Lat N or S, and the Dep. or p E or W being sure to write them in the correct column. Fill in the Wind, Compass Courses, Leeway, Deviation, and Variation and distances given. Combine the Leeway, Deviation, Variation, in accordance with their letters or signs getting the Error. Apply the error to the Compass Course in degrees and get the True Course to the nearest whole degree counting ½ degrees as whole degrees. From Table 2 Bowd. fill in Diff. Lat. and Dep. or p columns. Combine the Northing and Southing and Easting and Westing in the manner shown in the form, it should be noted that it happens in this problem there are no Southings. Apply the resultant Diff. Lat. in accordance with the sign or letter of the greater N or S to the Lat. Dep., which gives the Latitude in or arrived at called in the forms Lat.D.R. It is necessary to convert the miles change in Easting or Westing into minutes of Longitude which is done on the Middle Latitude basis. The summation of the Northings and Southings gives 229.01 minutes or miles which reduces to 3° 49′ N, which applying to the Lat. Dep. gives 0° 01.5′ S as the Lat. D. R. The summation of the p E, and p W, columns gives p W as the greater therefore subtract p E from p W and the result gives p W 23.77 miles Westing. To convert into minutes of Longitude use the mean of Lat. Dep. and Lat. D. R. as angle and using Table 2 we find the number in Dist. column corresponding to 23.77 in Lat. Column. The mean Lat. is 2° and the number in Lat. column 23.8 we therefore apply 23.8′ Longitude W to the Long. Dep. getting 32° 49.3′ W as the Longitude in or arrived at called Long. D. R. in the forms.

Continuing the Dead Reckoning in accordance with the run to Noon as given we get Lat D. R. 0° 11.6′ N and Long. D. R. 33° 05.5′ W for convenience we bring it down on the line just above Lat. Obs. and Long. Obs, filling in after Lat. Obs. and Long Obs. the observation position given. The Set and Drift

is found the same as if we wanted the Course and Distance from the D. R. position to the Observed position. Since Lat. D. R. and Lat. Obs. are the same name Diff. Lat. is their difference and since Lat. Obs. is North of the Lat. D. R. is marked N. Since Long. D. R. and Long. Obs. are the same name Diff. Long. is their difference and as Long. Obs. is West of Long. D. R. is marked W. The Diff. Long. is converted into Dep. or p by using the mean of Lat. Obs. and Lat. D. R. as the angle and Diff. Long. as Dist. and by Table 2 Bowditch the number in the Lat. column is the miles Dep. or p. With Diff. Lat. and p as arguments from Table 2 Bowd. we find the angle which is the Set, and Dist is the Total drift, the quadrant or marking of the angle being determined from the Markings of Diff. Lat. and Diff. Long. The total drift is divided by the elapsed time or length of the day giving the drift in miles per hour.

The form further provides for putting in the average wind for the elapsed time obtained from the log and reduced to True Direction, force of the wind Beaufort scale, temperature of the water in degrees, and the color of the water.

PRACTICAL EXAMPLES

(38) Steaming on course NNW ½ W p.s.c. speed of the ship 12.3 knots San Lucas, Lower California, was sighted at 5:10 p.m. bearing N ½ E p.s.c. At 6:10 p.m. San Lucas bore NE by N p.s.c. The Dev. on NNW ½ W − 3° 30′ W and Var. + 11° 00′ E.

Required the Distance Off and Latitude and Longitude at the 2nd Bearing and Distance San Lucas was passed abeam.

(39) Steaming on course S 60° E p.s.c. p. log 98.3 Mazatlan Lighthouse, Mexico, was sighted bearing S 81° E p.s.c.; continued on course S 60° E p.s.c. when p. log. 106.5 Mazatlan Light bore N 58° E Dev. +3° 30′ E, Var. + 10° 00′ E, Required the Distance Off at the 2nd Bearing, the Distance the Light will be passed abeam, and position Latitude and Longitude at the 2nd Bearing.

(40) Took departure from Lat. 34° 06′ 20″ S, Long. 172° 08′ 49″ E, bearing S by W ½ W distant 12.3 miles, ship's head NE by E ¾ E, Dev. + 7° 30′ E, Var. 14° 30′ E, wind N by W leeway ½ point. Steered the following courses and distances,—NE by E ¾ E p.s.c., 38.6 miles, Dev. + 7° 30′ E, Var + 14° 30′ E, wind N by W, leeway ¼ point; N by E ½ E p.s.c., 87.0 miles, Dev. + 5° 15′ E, Var. + 14° 30′ E, wind NW by W, leeway ¼ point; East p.s.c., 150 miles, Dev. 5° 15′ E, Var. 15° 00′ E, wind W by N, leeway 0. Required the Latitude and Longitude in by Dead Reckoning.

(41) At 7:05 p.m. 23 December 1920 on course SE p.s.c. Dev. 1° 15′ W, speed of the ship 12.5 knots, Cape Henry, Virginia, bore WNW ¾ W p.s.c. At 7:25 p.m. Cape Henry bore NW by W ¼ W p.s.c., on course SE p.s.c. Var. 5° 30′ W. At 8:00 p.m. a course N 77° E True is to be set.

Required the Magnetic Course corresponding to N 77° E True and if the Dev. on that course is 2° 30′ W what compass course is set? Having set the compass course corresponding to N 77° E True with estimated speed of the ship 12.5 knots and with Var. increasing 1° for every fifty miles of distance, required the Latitude and Longitude in by Dead Reckoning at 7:30 a.m. 24 December 1920.

Note—Latitude and Longitude of the Points of Departure are given in Bowditch Practical Navigator.

McCRACKEN FORM 1

DEAD RECKONING—DISTANCE OFF (5A BOWD)—SET AND DRIFT

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Civil Date

Wind	Comp. C°s	Leeway°	Dev.°	Var. °	Error °	True C °	p. Log	Dist.	ΔL ′ N	ΔL ′ S	p ′ E	p ′ W
	81° 34′		+3° 15′	−18° 30′	−15° 15′	66°		26.5	10.78		24.21	
N by W	59° 04′	+5° 38′	+3° 15′	−18° 30′	− 9° 37′	49°		55.8	36.61		42.11	
South	16° 53′	+0° 00′	+2° 15′	−17° 00′	−14° 45′	2°		105.8	105.70		3.70	
NE	329° 04′	−2° 49′	−1° 15′	−16° 00′	−20° 04′	309°		120.7	75.92			93.79
									229.01		70.02	93.79
												70.02
												23.77
NE	329° 04′	−2° 49′	−1° 15′W	−16° 00′	−20° 04′	309°		20.8	13.1			16.16

								Multiplier		Distance	
						Pts. From N	Diff.	Dist Off	Abeam	Off	Abeam
L. Dep	3° 50.5′ S	λ Dep	32° 25.5′ W								
Δ L.	3° 49.0′ N	Δλ	° 23.8′ W	Course	NE by E ¼ E	+37¼					
L D.R.	0° 01.5′ S	λD. R.	32° 49.3′ W	1st Bearing	NNW ½ W	+29½	7¾				
Δ L.	° 13.1′ N	Δλ	° 16.2′ W	2d Bearing	W ¾ S	+23¼	14	1.06	.41	26.5	10.25
L D.R.	° ′	λD. R.	° ′				Dist Run	25	25		
Δ L	° ′	Δλ	° ′					530	205		
L D.R.	0° 11.6′ N	λD. R.	33° 05.5′ W	L. A. Noon				212	82		
L. Obs.	0° 48.5′ N	λ Obs	33° 31 1′ W	L. A. Noon				26.5	10.25		
Δ L	36.9′ N	Δλ	25.6′ W								
Set	325°	p	25.6′	Total Drift, 45.05 miles.							

Drift .82 m. p. h.; Length Day, 55 h 04 m; Av. Wind, 218° True; Force, 4; Temp. Water, °; Color Water.

McCRACKEN FORM 1

DEAD RECKONING—DISTANCE OFF (5A BOWD)—SET AND DRIFT

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Civil Date

WIND	COMP. C°s	LEEWAY°	DEV.°	VAR. °	ERROR °	TRUE C °	p. LOG	DIST. ′	ΔL ′ N	ΔL ′ S	p ′ E	p ′ W

L. Dep	° ′	λ Dep	° ′
Δ L.	° ′	Δλ	° ′
L D.R.	° ′	λD. R.	° ′
Δ L.	° ′	Δλ	° ′
L D.R.	° ′	λD. R.	° ′
Δ L	° ′	Δλ	° ′
L D.R.	° ′	λD. R.	° ′
L Obs.	° ′	λ Obs	° ′
Δ L	′	Δλ	′
Set	°	p	′

		PTS. FROM N	DIFF.	MULTIPLIER		DISTANCE	
				DIST OFF	ABEAM	OFF	ABEAM
Course		+					
1st Bearing		+					
2d Bearing		+					

Dist Run

L. A. Noon

L. A. Noon

Total Drift, miles.

Drift m. p. h.; Length Day, h m; Av. Wind, ° True; Force, ; Temp. Water, °; Color Water

THESE FORMS CAN BE PURCHASED (IN PADS OF 25) FROM YOUR DEALER OR BY MAIL FROM J. J. McCRACKEN, NORFOLK, VA.

CHAPTER 2

McCracken Form 2

Course and Distance.

Middle Latitude Course and Distance—In this method the difference between Latitude of Derture and Latitude of Destination is reduced to minutes of arc or miles, the difference between Longide of Departure and Longitude of Destination is reduced to minutes of arc, and the minutes of arc of ference in Longitude reduced to miles by the assumption that the miles of Dep. or p equals the number minutes of Longitude multiplied by the cosine of the mean of the Lat. Dep. and the Lat. Des. A rightgled triangle is formed by the Diff.Lat. as one side about the right angle and the Diff.Long. reduced Dep. or p as the other side about the right angle, the Course angle being the angle adjacent to the ff. Lat. and opposite to Dep. or p, the distance being the hypothenuse of the triangle. For Practical ıvigation Purposes Table 2 Bowd. to nearest degree of angle and four digits of numbers is sufficiently curate, and is invariably used by the best Practical Navigators in solving this problem. If however eater accuracy is desired tangent of course angle equals p divided by the Diff. Lat. and Distance equals ff. Lat. times the secant of the course angle or p times cosecant of the course angle. The form is dened for the use of Table 2 Bowditch.

rite in after Lat. Dep. and Long. Dep. the Latitude and Longitude of Departure, and after Lat. Des. d Long. Des. the Latitude and Longitude of Destination, being sure to write after them the letters N, E or W as the case may be, then proceed in accordance with the following precepts:—

Lat. Dep. and Lat. Des. the same name Diff. Lat. is their difference. If Lat. Des. is greater than Lat. Dep. and of the same name, Diff. Lat. is marked the same name as Lat. Des. If Lat. Des. is less than Lat. Dep. and of the same name, Diff. Lat. is marked opposite name to Lat. Des.

Lat. Dep. and Lat. Des. of different name Diff. Lat. is their sum and is marked the same name as Lat. Des.

Long. Dep. and Long. Des. of same name Diff. Long. is their difference. If Long. Des. is greater than Long. Dep. and the same name Diff. Long. is marked the same as Long. Dep. If Long. Des. is less than Long. Dep. and same name Diff. Long. is marked opposite name to Long. Des.

Long. Dep. and Long. Des. of different name Diff. Long. is their sum and is marked the same name as Long. Des. If the Long. Dep. and Long. Des. are different name and their sum greater than 180°, Diff. Long. is their sum subtracted from 360° and Diff. Long. is marked opposite to Long. Des. and same as Long. Dep., it also shows the 180th Meridian will be crossed.

Dep. or p is marked the same as the Diff. Long.

er getting Diff. Lat. and Diff. Long. and properly naming or marking them, it is necessary to get Dep. p. This is done by using the mean of Lat. Dep. and Lat. Des. as angle and from Table 2 Bowd. finding number in the Lat. column corresponding to Diff. Long. reduced to minutes of arc in Dist. column. th Diff. Lat. and p as arguments we use Table 2 Bowd. to find their coincidence, the angle being indied by the letters after Diff. Lat. and p and the Distance the corresponding number in the Dist column. emember the precepts and cautions given you in Chapter B about the use of Table 2 Bowditch espelly about using the greater of the two for interpolating for Dist. after the closest coincidence of Diff. t. and p has been found.)

EXAMPLE

d the Course and Distance by Middle Latitude Sailing from Chesapeake Bay Entrance Gas and istle Buoy 2CB, Lat. 36° 51.9′ N and Long. 75° 51′ W, to Lat. 43° 00.0′ N and Long. 50° 00′ W: above example is worked out on appended form.

Put in Lat. Dep. and Lat. Des. Since Lat. Des. and Lat. Dep. are same name and Lat. Des. greater the Diff. Lat. is their difference and has the same name as the Lat. Des. which is North, the difference then is 6° 08.1′ N which further reduces to 368.1′ N.

Long. Dep. and Long. Des. are same name and Long. Des. is less than Long. Dep., therefore Diff. Long. is their difference and has opposite name to Long.Des. The difference is 25° 51′ E which reduces to 1551′ E. The Middle Latitude to nearest degree ½ (36° 51.9′ + 43° 00′) = 39° 56′ or 40° to the nearest degree. Turning to Table 2 Bowd. with angle 40° it is desired to find number in Lat. column corresponding to Dist. 1551. Dist. 155 has Lat. 118.7 therefore 1550 would have 1187 and Dist. 1 has Lat. .8 therefore 1551 would have 1187.8 which by holding to the four digit practice is 1188. With 368.1 as Lat. and 1188 as Dep. as arguments from Table 2 Bowd. the nearest coincidence is under course angle 73 and since Diff. Lat. is N and Diff. Long. E it is marked N73° E just 73°. In Dep. column the nearest we find to sequence of figures 1188 is 118.6, which gives 124 in Dist. Column therefore 1186 would give 1240, Dep. 1.9 gives Dist. 2 therefore Dep. 1187.9 gives Dist. 1242, which is quite close enough for practical purposes so we get Course 73° and Distance 1242 miles.

Mercator, Course and Distance—Perform the same steps as in Middle Latitude, that is fill in the Latitude and Longitude of Departure and Destination, obtain the Diff. Lat. and Diff. Long. under the same precepts, and mark them the same way N,S,E or W as the case may be. After M and M′ in the form pick out from Table 3 Bowd. the Meridional Parts corresponding to Lat. Dep. and Lat. Des. It should be noted in Table 3 that the degrees are given in horizontal columns and minutes in vertical columns and it is sufficiently accurate for Navigational purposes to pick out to the nearest whole minute of Latitude. The M and M′ are combined exactly in the same way and marked the same as the Lat. Dep. and Lat. Des. and should always be greater than the Diff. Lat. In the form the course is found from its cotangent cot C = dM divided by dL and Distance equals dL multiplied by the secant C.

EXAMPLE

Find the Mercator Course and Distance from Lat. 36° 51.9′ N and Long. 75° 51′ W to Lat. 43° 00′ N and as Long. 50° 00′ W.

Fill in Lat. Dep. and Long. Dep., Lat Des. and Long. Des., and obtain dL and dλ exactly the same way in the Middle Latitude method.

From Table 3 Bowd. pick out M for Lat. Dep. and M′ for Lat. Des. which gives for M 2368.5 and M′ 2847.1, dM is obtained in accordance with the same rules as dL and is marked the same name as dL. In finding M corresponding to Lat. 36° 51.9′ interpolation to tenths of minutes was used, but it was not necessary for practical purposes, we could have used M for Lat. 36° 52′ without affecting the practical results. From Table 42 Bowd. fill in log dL 2.56597, log dM 2.67997, and log dλ 3.19061. Subtract log dL from log dM giving 9.48936 − 10 as the log cot C. From Table 44 Bowd. find C 72° 51′ from its log cot 9.48936 − 10, marking it N and E in accordance with the marking of dL and dλ or just 72° 51 since it is N and E, which to the nearest degree reduces to 73° which is the same as under Middle Latitude. Pick out the sec C and add it to log dL getting log 3.09633 then from Table 42 Bowd. find the number corresponding to this log which is 1248.3 the Distance by Mercator Sailing.

Great Circle Course and Distance AQUINO—In solving Great Circle by the Aquino Tables the Difference in Longitudes between Dep. and Des. is considered as the hour angle t and Lat. Des. as declination d, when the astronomical triangle so formed is solved for altitude h and azimuth z. The complement of h that is 90°-h is the Great Circle distance and the azimuth Z is the first course, the angular distance reduced to minutes of arc gives the sea miles of distance. The precepts will be found at the bottom of McCracken Forms 4 and 5.

This method presents some advantages for quickness when the distances are between 600 and 5000 miles Due to the avoidance of interpolation in the Aquino method by assuming a Latitude and Longitude different from the actual position of Departure, the distance may be in error as much as thirty miles, but the course angle will seldom be enough out so that it is not correct to the nearest degree.

EXAMPLE

Find the Great Circle Course and Distance by Aquino Tables between Lat. 36° 51.9′ N and Long. 75° 51′ W, and Lat. 43° 00′ N and Long. 50° 00′ W.

Get the difference in Long. by the rules given under Middle Latitude sailing which in this case is 25° 51′ E, be sure to mark it E or W as the case may be, as you then know how to mark the course angle when you get it. With $d\lambda$ used as t and Lat. Des. as d as arguments enter the Aquino Tables, under $a = 18°\ 30'$ will be found the closest coincidence giving $b = 46°$. Combining Lat. to nearest degree as near Lat. Dep. as possible we use 37° 00′. In accordance with the precepts given McCracken Form 4 and 5, $C = b - L = 46° - 37° = 9°$, therefore from the tables $h = 69°\ 30'$, and $Z = 64°\ 57'$ less than 90° therefore. North and as $d\lambda$ is E also East. The Great Circle Distance is $90° - h$ or $20°\ 30' = 1230$ miles.

The first course N 64° 57′ E or to the nearest degree 65°.

Practical Great Circle Course and Distance—The practical method of finding the Great Circle Course and Distance, is to take the Great Circle Chart and connect the position of Departure and position of Destination by a straight line, which is the Great Circle Track between them on the Great Circle Chart. From this plotted line on the Great Circle Chart, it will be seen whether intervening shoals, land, or other dangers to Navigation prevent the using of the Great Circle Track, and how much we must modify it. It may be necessary to divide the route into a number of Great Circles or to use a combination with Middle Latitude or Mercator Courses and Distances. Having decided on the Track or Tracks from the Great Circle Chart we transfer various position points on the Great Circles to the Pilot Chart connecting the position points by straight lines. It may be that the current, wind, fog percentage, opposite steamer tracks, etc. makes the shortest route on paper disadvantageous or dangerous, so that a further modification may be advisable. The position points of the modified or Practical Great Circle Track may now be transferred to a Mercator Chart or Plotting Sheets and the Courses and Distances found. These Courses are the Practical Great Circle Courses and the sum of the Distances, the Practical Great Circle Distance. The method given on the Great Circle Chart of finding the first course is interesting but has no practical value, the method of finding the Distance is valuable only as a check on the results obtained by summation of the Practical Great Circle Distances. In McCracken Form 2 the Position Points are filled in beginning with the Point of Departure and following in order to the place of Destination. The Differences in Latitude, dL, and Longitude, $d\lambda$, are filled in and the courses and distances between the position points found by the Middle Latitude method. The distances are added up giving the Total Distance of the Practical Great Circle Distance.

In selecting position points, the object is to get distances between two and three hundred miles apart, to avoid changes of course less than 1°, and greater than 5°. If the following is followed almost invariably, the desired result will be obtained—when the difference in Latitude is less than the Difference in Longitude between point of Departure and Destination, select positions five degrees apart in Longitude, it being convenient to take them to the nearest five degrees of a multiple of five for the first position point; when the difference in Latitude between points of Departure and Destination is greater than the difference of Longitude, select position points four degrees apart in Latitude.

EXAMPLE

The Position Points for the Practical Great Circle Track are as follows— Lat. 36° 51.9′ N, Long. 75° 51′ W; Lat. 37° 10′ N, Long. 75° 00′ W; Lat. 38° 45′ N, Long. 70° 00′ W; Lat. 40° 15′ N, Long. 65° 00′ W; Lat. 41° 25′ W, Long. 60° 00′ W; Lat. 42° 20′ N, Long. 55° 00′ W; Lat. 43° 00′ N, Long. 50° 00′ W. Find the Practical Great Circle Courses and the Practical Great Circle Distance.

Put down the Latitude and Longitude of the position points in the places provided in the form in their proper sequence. Fill in the $d\lambda$ and dL the same as in Middle Latitude sailing being sure to mark them N,S,E or W as the case may be. It should be noted as the Diff. Lat. between first and last Lat. is less than the Diff. Long. that position points have been selected five degrees of Longitude apart and the nearest Longitude after Dep. a multiple of 5 is 75°. It should be noted that the Middle Latitude for the 1st p is the mean of 36° 51.9′ and 37° 10′, 2nd p mean of 37° 10′ and 38° 45′, etc.

PRACTICAL PROBLEMS

Required Middle Latitude, Mercator, Great Circle Aquino, and the Practical Great Circle Courses and Distances between the following points.

(42)	Lat. Dep. 43° 00′ N	Long. Dep. 50° 00′ W
	Lat. Des. 58° 40′ N	Long. Des. 14° 00′ W
(43)	Lat. Dep. 43° 00′ N	Long. Dep. 55° 00′ W
	Lat. Des. 51° 20′	Long. Des. 9° 35′ W
(44)	Lat. Dep. 43° 00′ N	Long. Dep. 50° 00′ W
	Lat. Dep. 36° 50′ N	Long. Dep. 8° 50′ W
(45)	Lat. Dep. 36° 52′ N	Long. Dep. 75° 51′ W
	Lat. Des. 30° 00′ S	Long. Des. 10° 00′ E
(46)	Lat. Dep. 5° 10′ N	Long. Dep. 80° 00′ W
	Lat. Des. 42° 00′ S	Long. Des. 178° 00′ E

McCRACKEN FORM 2

COURSE AND DISTANCE

Civil Date

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Middle Latitude				Mercator					Gr. Cir. Aquino	
Lat. Dep.	36° 51.9′ N	λong.	Dep. 75° 51.0′ W	M 2368.5′						
Lat. Des.	43° 00.0′ N	λong.	Des. 50° 00.0′ W	M′ 2847.1′	ΔL	368.1′	log + 2.56597		a	18° 30′
									b	46° 00′
ΔL.	6° 08.1′ N	Δλ	25° 51.0′ E	ΔM 478.6′ N	log+	2.67997			L. Dep.	37° 00′
	360.′		1500.0′	Δλ 1551.0′ E	log−	3.19061			C	9° 00′
ΔL.	368.1′ p = 1188′	Δλ	1551.0′	C. N. 72°51′ E	cot	9.48936	Sec. + .53036		h	69° 30′
Course N 73° E	Dist. 1242′			Dist. 1248.3′			log	3.09633	90° − h	20° 30′
										1200′

Position Points Polar (Gr. c.) Chart H. O. 1280

Lat.	36°	51.9′ N	λong	75°	51.0′ W												Dist.	1230′
Lat.	37°	10.0′ N	λong	75°	′ W	ΔL	18.1′ N	Δλ	51′ E	p	40.7′	C	66°	Dist.	44.6′		Z	64° 57′
Lat.	38°	45.0′ N	λong	70°	′ W	ΔL	95.0′ N	Δλ	300′ E	p	236.4′	C	68°	Dist.	255.0′		Course	64° 57′
Lat.	40°	15.0′ N	λong	65°	′ W	ΔL	90.0′ N	Δλ	300′ E	p	229.8′	C	69°	Dist.	246.1′			
Lat.	41°	25.0′ N	λong	60°	′ W	ΔL	70.0′ N	Δλ	300′ E	p	226.4′	C	73°	Dist.	236.8′			
Lat.	42°	20.0′ N	λong	55°	′ W	ΔL	55.0′ N	Δλ	300′ E	p	222.9′	C	76°	Dist.	229.7′			
Lat.	43°	00.0′ N	λong	50°	′ W	ΔL	40.0′ N	Δλ	300′ E	p	219.4′	C	80°	Dist.	222.8′		1235.0′	
Lat.	°	′	λong	°	′	ΔL	′	Δλ	′ E	p	′	C	°	Dist.	′			
Lat.	°	′	λong	°	′	ΔL	′	Δλ	′ E	p	′	C	°	Dist.	′			
Lat.	°	′	λong	°	′	ΔL	′	Δλ	′ E	p	′	C	°	Dist.	′			
Lat.	°	′	λong	°	′	ΔL	′	Δλ	′ E	p	′	C	°	Dist.	′			
Lat.	°	′	λong	°	′	ΔL	′	Δλ	′ E	p	′	C	°	Dist.	′			
Lat.	°	′	λong	°	′	ΔL	′	Δλ	′ E	p	′	C	°	Dist.	′			

Total Dist.

COURSE AND DISTANCE

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Civil Date

Middle Latitude						Mercator					Gr. Cir. Aquino		
Lat. Dep.	°	′	λong. Dep.	°	′	M	′				a	°	′
Lat. Des.	°	′	λong. Des.	°	′	M′	′	ΔL	′	log +	b	°	′
ΔL.	°	′	$\Delta\lambda$	°	′	ΔM	′	log +			L. Dep.	°	′
		′			′	$\Delta\lambda$	′	log −			C	°	′
ΔL.		′ p = ′	$\Delta\lambda$		′	C. °	′	cot		Sec. +	h	°	′
Course	°	Dist. ′				Dist.	′			log	90° − h	°	′

Position Points Polar (Gr. C.) Chart H. O. 1280

Lat.	°	′	λong	°	′											Dist.			′
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′	Z	°		′
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′	Course	°		′
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
Lat.	°	′	λong	°	′	ΔL	′	$\Delta\lambda$	′	p	′	C	°	Dist.	′				
														Total Dist.	′				

THESE FORMS CAN BE PURCHASED (IN PADS OF 25) FROM YOUR DEALER OR BY MAIL FROM J. J. McCRACKEN, NORFOLK, VA.

CHAPTER F

Astronomical Data and Nautical Almanac

Celestial Sphere—For Practical Astronomical Navigation purposes the Universe is considered as a varying sphere, which has an infinite radius and the earth's center as its center at any particular instant of time, the prolongation of the earth's poles to the surface of the celestial sphere being the celestial poles. All bodies or positions are considered as capable of being projected on the surface of this sphere by a line drawn from the center of the earth through the center of the body and piercing the surface of the celestial sphere. The points where the lines of projection pierce the surface of the celestial sphere are known as Zeniths of the bodies or positions, when on the surface of the hemisphere including the elevated or nearest pole.

Astronomical Triangle—The spherical triangle formed on the celestial sphere by the three planes passing through—the zenith of the observer, the center of the earth, and the elevated pole of the celestial sphere; the elevated pole, the center of the earth, and the projection of the observed body on the surface of the celestial sphere; and the zenith of the observer, the center of the earth, and the projection of the observed body on the surface of the celestial sphere; is called the astronomical triangle. Its sides are known as the Polar Distance of the Observer or co-Latitude, the Polar Distance of the Observed Body, and the Zenith Distance or co-Altitude of the Observed Body, respectively.

Astronomical Navigation—The process of obtaining, the various elements that make up the Astronomical Triangle, calculating unknown elements from known or assumed ones, and adapting the results to locating positions on the earth's surface, is known as Astronomical Navigation.

Time—As was stated under "Celestial Sphere" the relative position of the celestial sphere, therefore the Astronomical Triangle, depends upon the particular instant of time. The position of the earth's center is continually changing relative to the Sun, which is believed to be fixed and the center of the universe, also the inclination of the earth's axis of rotation is continually changing, thereby changing the position of the celestial poles.

The fundamental basis of time is the number of rotations of the earth on its axis in a complete revolution or passage around the Sun. The time interval for a complete passage of the earth around the Real or Apparent Sun is called the Solar Year and this time interval is nearly constant from year to year. This yearly time interval divided by the number of rotations and fraction thereof of the earth on its axis during the Solar Year is known as the Mean Solar Day, which is the basis of all clock time and time interval measurement. The Mean Solar Day is subdivided into 24 hours, each hour subdivided into 60 minutes, and each minute subidvided into 60 seconds, this Mean Solar Time is known as Mean Time. Since the Mean Solar Day also represents, one mean rotation of the earth on its axis, and in one rotation the earth describes an arc or angle of 360° measurement, in the Practice of Navigation, we use Time and Angular Rotation synonomously, that is 24 hours of Time Measurement is considered as 360° of angular time measurement. We call this element Hour Angle, usually represented by the letter t, measured either in hours, minutes, and seconds or degrees, minutes, and seconds of arc. In order to simplify and standardize deductions, calculations, and the language of Navigation, a ficticious sun is created, sometimes called the 2nd Mean Sun, which moves a complete trip around in the plane of the Equator from East to West at a constant rate of speed equal to the Mean Solar Day. Since the Earth rotates on its axis from West to East, this fictitious sun moves around in the plane of the Equator from East to West, following approximately the Apparent Sun relative to any particular Meridian from day to day. The angular difference between a plane passing through the center of the Real or Apparent Sun, the center of the earth and the earth's poles and a plane passing through the center of the Mean Sun, the center of the earth, and the earth's poles, at any instant of time, is called the Equation of Time. By means of chronometers, clocks, watches, etc., the mean time interval from any particular instant may be determined, and if the relative positions of the Apparent Sun and Mean Sun, and the Equation of Time, are known at the beginning of the interval, from the Nautical Almanac we may find, the elements necessary to solve the astrono-

mical triangle at any instant of time. In ordinary life and in the Nautical Almanac, the beginning of the time interval is taken as the position of the Mean Sun at Greenwich Mean Noon, on the Calendar date of 1 January of each calendar year, and the Relative Position of various Astronomical Bodies and the different elements or functions, are figured or predicted, for certain specified time intervals from the instant of Greenwich Mean Noon of 1st January of the current calendar year. It is therefore only necessary to know, the Greenwich Mean Time or Greenwich Mean Time interval from 1 January of the current year, in order to determine the relative position of the center of the earth, and all Astronomical Bodies available for Navigation purposes. In the Nautical Almanac, the time intervals and elements fixing the relative positions of the various bodies are given in intervals from Greenwich Mean Noon of the current calendar day, and frequently for each two hours of mean time thereafter.

It is very important for the Navigator to thoroughly comprehend the significance of this fictitious Mean Sun or Mean Time, in order to intelligently and properly use the Nautical Almanac in Practical Navigation, and from the Calendar or Civil Date and the chronometer time, to determine the Astronomical Greenwich Mean Date, and the time interval to or from the Greenwich Mean Noon or the 0 hours of that date.

Civil Time—In view of the fact, that in the daily rotation of the Earth on its axis, the Sun is the great source of light, the day is divided into a period of light and one of darkness. The Civil Date begins in the period of darkness at the passage of the Mean Sun over the Meridian 180° or 12 hours from the Local Standard Meridian of reference. The interval from lower passage to Upper Passage or Noon is known as a.m. time, and from Noon to Lower Passage or Midnight is known as p.m. time, the clocks or watches keeping time from 12 hours to twelve hours, the first hour after 12 being marked 1 and increasing in one hour intervals up to twelve. The clock time of Noon is marked 12:00 M and Midnight 12:00 p.m., after 12:00 M it is marked p.m. thus 12:20 p.m. would be twenty minutes after Noon, and 12:20 a.m. would be twenty minutes after Midnight.

Local Apparent Time—The Local Apparent Time is the time of the Real or Apparent Sun and it represents in hours, minutes, and seconds, the angle at any instant of time between the Local Celestial Meridian and the Celestial Meridian of the Apparent Sun. It, like Civil Time begins the day at lower culmination, that is when the Apparent Sun is on the Meridian 180° from the Local Meridian and is marked a.m. and p.m. the same as Civil Time running from 12 hours to 12 hours.

Since Difference in Longitude is the difference in angle between the planes of the Meridians of any two places, it follows that differences in Local Apparent Times is the difference of their Longitudes, if one place is the Standard Meridian, as for instance the Meridian of Greenwich, the difference in Local Apparent Times is the Longitude.

Local Mean Time—When instead of using the passage of the Mean Sun over the Greenwich Meridian as the Noon of reference, we use its passage over the Local Meridian, and measure the time intervals from the local passage of the Mean Sun, we have Local Mean Time. The day begins at Midnight as in the case of the Civil Time and is marked a.m. and p.m. in the same manner. The difference in Local Mean Times of two places is also their difference in Longitude.

Astronomical Time—The Astronomical Day begins with the passage of the Sun over the Local Meridian at upper passage and runs from 0 hours to 24 hours. The Astronomical Date begins twelve hours later than the Civil Date, that is a.m. Civil Time is one day ahead of Astronomical Time but also twelve hours behind, whereas p.m. Civil Time and Astronomical Time are the same date and numerical hours, minutes, and seconds. In view of the Nautical Almanac giving the different elements corresponding to Greenwich Mean Astronomical Time, when a.m., Civil or Local Time is given, you must add twelve hours and use as the Astronomical Date, the date of the previous day.

Sidereal Time or Star Time—The interval between two successive transits of the Vernal Equinox over the same Meridian is known as the Sidereal Day. The Hour Angle of the Vernal Equinox at any particular instant of time with any particular Meridian is the Sidereal Time of that Meridian. It is measured on the Equator from the Meridian Westward to the Vernal Equinox, from 0 to 24 hours and is equal to the Right Ascension of the Meridian. The Sidereal Time of the Meridian of Greenwich, England, is known as the Greenwich Sidereal Time and of the Local Meridian, the Local Sidereal Time. The difference of Sidereal Times of any two Meridians is equal to their difference in Longitudes.

Right Ascension—The Right Ascension of a body is the angular distance its Circle of Declination is from the Vernal Equinox, measured on the Equator from the Circle of Declination Westward to the Vernal Equinox from 0 to 24 hours.

Hour Angle—The Hour Angle of any Body is the angle between the plane of its Meridian and the plane of the Local Meridian. It is measured on the Equator and in hours, minutes, and seconds of time or degrees, minutes, and seconds of arc. When the body is West of the Meridian it is marked plus and when East of the Meridian minus.

Declination—Declination is the angular Distance the body is North or South of the Celestial Equator and is synonomus to Latitude. It is measured in degrees, minutes, and seconds of arc and when North of the Equator is marked plus and South minus.

Chronometer—The chronometer is a very accurate and well made clock or time keeper. It should have a constant rate of gaining or losing and should be able to compensate itself for wide ranges of temperatures. Its error at a recent date should be accurately known and its daily rate of gaining or losing. It is the practice to rate them every ten days, and now that we have the radio tick, in most quarters of the World daily comparisons and errors may be obtained. It is also the practice to get the error on Greenwich Mean Time and the rate, so that by applying the error, corrected for the rate, to any instant of chronometer time, we may obtain the Greenwich Mean Time corresponding to any particular chronometer time. The chronometer should be kept, in a place free from wide temperature changes, free from vibration, and distant from electric machines or equipment. A chronometer book containing the errors and daily rates should be kept, the importance given in the past to temperature charts and curves is no longer of importance to the Practical Navigator, whose ship is equipped with radio, for with almost daily comparisons available and a reasonable rate, it is now unnecessary to bother with such uncertain theoretical theories. One chronometer on a ship equipped with radio is usually quite sufficient, certainly two is all that anyone should desire.

There is no Navigation Practice, that I more heartily condemn than the marking of time from the chronometer direct. Every observation should show the approximate ship time it was taken and should be timed from a good watch, set to ship's time. Then if you make mistakes in marking time or your timer does, there is some chance of catching it, especially the more common ones, such as an hour or five minutes or one minute in time. Make a practice of looking at the watch as soon after marking as possible to see if the minutes and hours have been correctly observed, the seconds of time can be depended on but you are going to find your timer and yourself human and you will save yourself much annoyance by assuring yourself personally that the hours and minutes have been correctly observed. When marking time from a watch the hours will generally be found correct but when marking time from a chronometer mistakes of hours in time are not infrequently made. The speed of the ship times the elapsed times of observations gives the run, checks up the p. log if used and also allows you to estimate speed, etc. If you have been using the chronometer for the purpose of marking time direct, cut it out before it is too late, you may put a ship on the beach some day, if you do not.

When you use the watch in comparison with the chronometer cut out this C-W business, it is the logical thing to apply the chronometer error corrected for rate, to the chronometer time of comparison to get the G.M.T of comparison, and by applying the watch time of comparison to the G.M.T. of comparison to get the watch error on G.M.T. A Navigating watch should be set to ship's time and should have a daily rate of less than 15 seconds.

Sun's Declination and Equation Time—Beginning on page 6 and extending to page 29, Nautical Almanac are given the Sun's Declination and Equation of Time, for every two hours of Greenwich Astronomical Time from 1 January to 31 December. At the bottom of each day is given the hourly difference so that by inspection and a little mental arithmetic, we may determine the Declination and Equation of Time for any known instant of Greenwich Mean Astronomical Time. For Practical Navigation purposes it is sufficient to get it to the nearest whole hour of G.M.T. Remember that if the G.M.T. is obtained by chronometer and is p.m., the G.M.T. and G.M.As.T. are the same, if the G.M.T. is a.m., add twelve hours and use the civil date of the previous day to get G.M.As.T.

Apply the Equation of Time in accordance with note given at the bottom of the page in the Nautical Almanac.

EXAMPLE

C.T. 4—00—06, c.c. 3 m 22.6 s fast on G.M.T., W.T. 10—55—18, Longitude West, civil date a.m. 20 June 1920. Required the Sun's Declination and Equation of Time.

C.T.	4—00—06	
c.c. —	03—22.6 fast	
G.M.T.	3—56—43.4 p.m. (20th) as the Longitude is West and Local Time a.m.	

3—56—43.4 = 3.95 hours 20 June Greenwich Mean Astronomical Time.

	Sun's Declination	Equation Time
H.D.	0.0	.5
	1.95	1.95
	0.0	.975
2 Hrs. (20)	23° 26.6′	1m 18.1
	+23° 26.6′ North	—1m 19.1

EXAMPLE

10 May 1920, W. T. 4—30—02 a.m. Long. 69° 30′ W, W. Er. 4—40—49 slow on G.M.T. Required the G.S.T. and the L.S.T.

W.T. 4-30-02 a.m. 10 May =	As.T.	16-30-02	(9th)
	W.Er.	4-40-49	(slow)
	G.M.As.T.	21-10-51	(9th)
	R.A.M.O.	3-07-59.1	
	Corr.	3-28.8	
	G.S.T.	* 0-22-18.9	
	Long.	4-38-00	W
	L.S.T.	19-44-18.9	

*Note—Whenever the Sidereal Time is greater than 24 hours subtract 24 from the number of hours. In subtracting the Long. from the G.S.T. when Long. is West and the L.S.T. is greater add twenty-four hours to the G.S.T.

Planets and Stars—The finding of the Right Ascension and Declination of the Planets and Stars presents no difficulty. In the case of the planets, we reduce the elapsed time since G.M.N. to the fraction of a day, multiply the daily difference by the fraction, and apply the correction, if the element is increasing in value adding the correction but if decreasing in value subtracting the correction. The correction is not given for the fixed stars but the value of the element is given for each month as the change is very small.

The Moon—The Nautical Almanac gives, Right Ascension, Declination, Semi-diameter, and Horizontal Parallax, of the Moon for each two hour of Greenwich Astronomical Mean Time. Due to the large change in Right Ascension and Declination per hour, the additional corrections of Altitude for S. D. and H. P., and the difficulty of getting a well-defined cut of the Moon on the visible horizon, the best Practical Navigators, use the Moon only under provocation, that is, when they practically cannot get observations of anything else. It is an observation not to be despised in hazy or cloudy weather, good positions may be obtained by crossing it with a sun or star line, but in making a land fall or port from a Moon cross with some other observation an error of as much as five miles in any direction should be assumed. It is treated in the same way as a planet or star except that you get its altitude correction from another

ble. Table 2 H. O. No. 200. You find the G.S.T. or L.S.T. of the observation and obtain the hour ıgle by combining L.S.T. and the R.A. of the Moon.

ı pages 76-77 Nautical Almanac will be found G.M.T. of Upper Transit over the Meridian of Greenwich. ıis data is only useful to the Practical Navigator in finding the Time of High and Low Water, when e Port Establishment is known, and its use will be shown under the use of McCracken Form 12.

CHAPTER 3

McCracken Form 3

Sun Rise and Sun Set—Stars to be Observed—Polaris.

McCracken Form 3—This form is for use in preparing for evening and morning twilight observation, for obtaining Latitude by Polaris, and posting oneself on the available stars for fixing the Ship's Position. The time is past when the so-called eight o'clock Navigation is considered sufficient and it should not be long before Insurance Rates are going to be affected by the character of the Navigation used on our vessels.

Dead Reckoning Position at Sun Set or Sun Rise—After Lat. and Long. upper right hand part of the form, fill in the last Latitude and Longitude obtained by observation. This will ordinarily be the Noon position for Sun Set and the Evening Twilight or 8:00 p. m. position for Sun Rise. The watch times in the forms should always be the ship's time, so that the elapsed times in watch time multiplied by the speed of the ship, or the difference in p. log readings, will represent the distance run in the elapsed watch time.

Whether Table VI Naut. Al. or Table 10 Bowd. is used makes little difference in the results, personally I prefer Table 10 Bowd. for it is figured for a dip of 15′ and requires a little less interpolating, however for the beginner as the Nautical Almanac gives results in Local Mean Astronomical Time with precepts at the top of the page for converting into Local and Standard Times, it may be easier for him to use the Table VI Naut. Al.

By inspection take the time of Sun Rise or Sun Set given in either Table VI N.A. or Table 10 Bowd., using as Latitude the Latitude of Observation filled in the form as above. Apply corrections to this time for the approximate error of the watch on L. M.T., which when the watch is keeping L.A.T. is the Equation of Time applied as given in the N.A. and the change in time due to expected change in Longitude. It is only necessary to get this change of time due to expected change in Longitude to the nearest five minutes. Assume this corrected time to be the ship's time of Sun Rise or Sun Set for D.R. purposes. Find the elapsed time between the ship's time of the Observation Position and this assumed watch time, multiplying it by the speed of the ship to get the total distance run. Fill in the expected Compass Courses and the part of the total distance to be run on each course, reducing the Compass Courses to True Courses, and by Table 2 Bowd. work up the expected or approximate D.R. position. In applying the time correction for approximate change of Longitude, if steaming to the Eastward subtract it, if steaming to the Westward add it to the first L. M. T. picked out of Table 10 Bowd. or Table 2 N.A.

Time of Sun Rise or Sun Set—With the Latitude by D.R. as found above and the Local Date using either Table 10 Bowd. or Table VI, N.A. fill in the space for L.M.T. and L.As.M.T. o fSun Rise or Sun Set using the nearest whole degree of Latitude in interpolating. If the Long. by D.R. is East, subtract it from L.M.T. and L.As.M.T., if West add it to get G.M.T. and G.As.M.T. If the Watch error on G.M.T. is slow or plus we subtract, if fast or minus we add it to the G.M.T. to get the W.T. Sun R or S. If we use Table 10 Bowd. this is for Dip or height of eye 15′; if Table VI N.A. dip is 0, therefore to get the time for height of the bridge, when running lights go on and off, a correction must be applied and it may be assumed one minute for every 25′ of change in height of the eye, remembering that the higher the bridge the later Sunset and the earlier Sunrise.

To the L.As.M.T. add the Right Ascension of the Mean Sun pages 2-3 N.A. and add the correction for the Greenwich Mean Time Interval from Greenwich Mean Noon of the Greenwich Astronomical Date, the total is the Local Sidereal Time of the Watch Time Sun R or S. It should be noted that where the height of the bridge is taken into consideration, that it is marked W.T.App. Sun R or S. If working for Sun Rise draw a line through Set and the S in the form and if working for Sun Set draw a line through Rise and R in the form.

McCracken's Star Identification Protractor, Stars to be Observed—With McCracken's Star Identification Protractor, the L.S.T., the Lat. D.R., and the Hydrographic Office Star charts, the visible heavens at the time of L.S.T. may be investigated and Altitudes and Azimuths of the available stars with

their names may be set down in the form. The sextant may then be set to the Altitude of the Star desired and from the compass its direction by its azimuth obtained, when you can pick up and observe the star with excellent horizon when not visible to the naked eye.

Polaris—Under the line L.S.T. fill in after Lat. D.R. the Latitude obtained by D.R. and turning to Tab. I. N.A. pick out the correction for the L.S.T., apply this correction with opposite sign to that given in N.A. to the Lat. D.R., this will give the approximate Altitude of Polaris at Sun R or S. This altitude is used to find the correction for the observed h of Polaris, and to be able to set the sextant to pick it up while still invisible to the naked eye. Most modern Expert Navigators do not consider the Index Correction as belonging to the Altitude proper but to the instrument itself, where they have an index correction it is very small and they apply it to the instrument altitude by a process of mental arithmetic. They find the index correction either just before or just after taking a set of observations and use what they find each time. You can either wait for the observed altitude or use the Polaris h and from H. O. 200 Tab. 1 or Bowd. Tab. 46 get the Correction to be applied. This correction in the case of stars and planets is always minus. When the sextant h is observed it is filled in after hs, which combined with Corr. Tab. 46 Bowd., gives ho the True or real observed altitude reduced to the center of the earth. Just before or after taking the observation a comparison of the watch and chronometer is made which is provided for in right hand part of the form. C.Tc. is the chronometer time of comparison, and C.C. is the chronometer correction or error, when fast it is subtracted and slow added to C.Tc. to get the G.M.T. of comparison. W.Tc., the watch time of comparison, is then compared with G.M.Tc. in accordance with the following — East Longitude the G.M.T. is subtracted from the Watch Time to get the error and in West Longitude the Watch Time is subtracted from the G.M.T. to get the error, for the reason, that watches keep either L.A.T. or the L.M.T. of some nearby Standard Meridian, and it is desired that the Watch Error will represent the approximate Longitude within one hour of time, or show by its error and whether fast or slow, the Standard Meridian to which it is set. Fill in after Sun R or S,W,T., being careful not to get the W.T. App.Sun R or S, and find their difference getting ΔW.T. This Δ W.T. may be corrected for mean time interval, and adding up the total after filling in Sun R or S L.S.T. we get the Polaris L.S.T. With this Polaris L.S.T. from Tab. 1 page 107 N.A., we get the Corr. to be applied to the True Polaris Altitude, ho, to get the Latitude of Polaris observation. After the Lat. by Polaris write in the W.T. to the nearest minute and also bring up the Lat.D.R. to time of Polaris Observation, get the Drift in Lat. from time of Departure or Last Observation Position, which divided by the time interval gives miles per hour drift in Lat. Applying this drift with D.R. we can run the Lat. by Polaris up to some other time, as say 8:00 p.m. or 8:00 a.m., in accordance with Middle Latitude and Table 2 Bowd.

EXAMPLE

25 December 1920, 8:00 p.m. ship's time, keeping the Mean Time of the 75th Meridian West of Greenwich, passed the Chesapeake Bay Entrance Gas and Whistle Buoy 2CB close aboard, Lat. 36° 51.9′ N, Long. 75° 51′ W. The compass course is 82°, Dev. 1° 30′ E, and Var. 5° 30′ W. If the speed of the ship is 12.5 knots, and the Variation is increasing 1° to the Westward each fifty miles of distance, required the Watch Time of Sunrise, the L.S.T. of Sun Rise, Polaris h. Just before observing Polaris C.Tc. 11-52-30, C.C. 12 m 15.3 s fast G.M.T., W.Tc. 6-40-20. At W.T.6-45-00 observed Polaris 36° 31′, I. C. plus 1′ 20″ required the Lat. by Observation of Polaris and at 8:00 a.m. ship's time, 26 December 1920 Dep. 35′.

From Table 10 Bowd. Lat. 37° N and 22 December L.M.T. Sun R 7-09 and 2 January 7-13 therefore 26 December will be 7-09 plus 4/11 times 4 or 7-10-30 to the nearest half minute. Since the watch is keeping ship's time and that of the 75th M., as the Longitude at Departure is 75° 51′, the watch is fast 3 m 24 s on L.M.T. therefore the Watch Time provided the ship had not moved would be 7-13-54. Since we are steaming to the Eastward Sun R will be earlier by clock. The mean variation for the first fifty miles is 5-30 plus 6-30 divided by 2 which is 6° W and increasing 1° every fifty miles. The Dev. 1° 30′ E applied to 6° W gives Error 4° 30′ W. It is the practice to apply this to the True Course when in even degress, either as 4° or 5°, my practice is to call halves, units, in such cases, so I have applied 5° making the True Course 77° and for distance 50 miles, from Table 2 Bowd. Lat. 11.2 and Dep. 48.7. The change in Long. for Middle Lat. 37° 00′ is 4′ of time in four hours or 1′ per hour. Since the time of Sun R will be around 7:00 a.m., and the elapsed time from 8:00 p.m. of the night before 11 hours, the change in time due to change of Longitude will be about 11 minutes, which subtracted from 7-13-54 gives 7-02-54.

We therefore work up our D.R. to 7:00 a.m. 26 December as shown in the form getting 37° 24.3′ N and 73° 06.6′ W. Going to Table 10 Bowd. with 37° the nearest whole degree to the D.R. Lat. we get for L.M.T. Sun R 7-10-30 and L.As.M.T. Sun R 19-10-30 26 December. Converting Long. D.R. into hours, minutes, and seconds gives 4-52-26.4 which added to L.M.T. gives G.M.T. 0-02-56.4 p.m. Obtaining the Watch Error as shown in the appended form where the problem is solved 4-59-54.7 gives W.T. Sun R 7-03-01.7 to which the correction for the excess of bridge height over 15′ may be applied. The R.A. M. Sun and Correction for the Mean time interval past G.M.Noon gives L.S.T. 13-29-13.8. Filling in Lat. D.R. 37° 24.3′ and getting the correction for L.S.T. from Tab. 1 N.A., applying it to the Lat. D.R. using opposite sign to that given in the N.A. In the present case the N.A. gives plus therefore we subtract the correction from the Lat. D.R. to get the Polaris h at Sun R, getting 36° 17.2′. The following morning 26 December we set our sextant for an altitude of 36° 17′ and by looking in the direction of True North sweeping the horizon and moving the horizon glass up and down vertically a small amount, Polaris may be picked up and brought to coincidence with the horizon. This is not so important in the case of morning twilight stars, as when they are still bright we can bring them down, note their approximate height and then wait for the horizon to get sufficiently well defined to accurately observe them. In the case of evening twilight, the advantage of knowing the approximate height of the Navigational stars, is a great advantage in getting accurate observations while the horizon is good, especially in the case of Polaris which is not a particularly bright star. Using the Aquino tables the advantages of the use of Polaris are not very much as the Planets and other Navigational stars are much brighter, they may be observed with a better horizon, and the time and labor in working out the sight is not much greater.

The approximate h will be close enough for picking out the cor. for the observed h from Tab. 1 H.O. 200, or Tab. 46 Bowd., and as stated before the I.C. is considered by the best Navigators as an instrument reading correction and is applied to the sextant h at time of reading it, or when they record the h in their Navigation work book. The I.C. plus 1′ 20″ is reduced to tenths of minutes giving 1.2′ and the correction obtained from Tab. 1, H.O. 200, is 7.1′ which in the case of stars is always minus, so that for the total correction we get minus 5.9′ which applied to the sextant h 36° 31′ gives observed h 36° 25.1′. It is now necessary to find the L.S.T. of the Polaris h. As the change in correction for altitude to get latitude is not large and for practical purposes we only work to tenths of minutes, accuracy closer than 1 minute in the L.S.T. of Polaris is unnecessary, and if our watch conforms to the requirement for a Navigating watch, the watch error at the actual time of observation is not so important so that the watch error of the night before will be sufficient for Polaris sight, but for the other stars and planets the watch error at time of observation either shortly before or after is necessary. The Sun R W.T. 7-03-01.7 and Polaris W.T. observation are compared and their Δ.W.T. set down in the right hand part of the form. When Polaris is earlier or less than Sun R or Sun S Δ.W.T. is minus, also cor. Δ.W.T. is minus, and this is usually the case in morning twilight observations, as they as a rule have to be taken within the half hour period preceding Sun R. In the case of Sunset just the opposite occurs.

Adding up according to sign Δ.W.T., cor. Δ.W.T. and the L.S.T. Sun R we get Polaris L.S.T. 13-11-09.1. Entering Table 1 N.A. with L.S.T. 13-11-09.1 we find for the correction to the Altitude 1° 06.8′ which is marked plus therefore added to ho giving as Lat. 37° 31.9′ N. The Polaris observation was taken at 6-45 a.m. therefore to 8:00 a.m. it is 1 h 15m and in that time the ship goes 15.4 miles on course 75°, which from table two gives change in Lat. 3.99 or 4′, the change due to drift .78 x 1.25 = 1.0′ and is N therefore the Lat. at 8:00 a.m. by Polaris is 37° 36.9′ N.

PRACTICAL EXAMPLES

(47) 13 June 1920 Lat. 35° 56.4′ N, Long. 32° 06′ W, L.A. Noon Ship and Watch Time, Course 273°, speed 10.2 knots, error watch on G.M.T. 2-06-44 slow. Required the Sunset data in accordance with McCracken Form 3. At 7-55-27 p.m. watch time observed Polaris h 34° 56.8′, dip 39′ height of eye Navigating Bridge, what is the Lat. by observation 8:00 p.m. ship time.

(48) 15 May 1920, Lat. 40° 00′ N, Long. 42° 20.5′ W, L. A. Noon ship and watch time, Course 90°, speed 9.5 knots. Required the Sunrise data in accordance with McCracken Form 3, error of the watch G.M.T. 2-52-04 slow, 16 May 1920. Observed Altitude of Polaris by sextant 40° 15′ W.T. 3-59-58, find the latitude by observation at 8:00 a.m. ship time. Dip 26 feet.

McCRACKEN FORM 3

SUN RISE/SET—STARS TO BE OBSERVED—POLARIS

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Civil Date—26 Dec. 1920

	Com. C°	Dev.°	Var.°		Error°	Tr. C.°	Dist.′	ΔL′	p′
	82	+1–30	−6° 00		−4.30	77	50.0	11.2	48.7
	82	+1–30	−7° 00		−5.30	76	50.0	12.1	48.5
	82	+1–30	−8° 00	7:00A.M.	−6.30	75	35.3	9.1	34.1
									131.3
7h 00m 6h 45m						75	− 3.1	.8S	2.99′
15m	= ¼ h ¼	× 12.3	= 3.1			75	15.4	3.99	

Lat.	36° 51.9′ N		λong.	75° 51.0′ W
ΔL.	° 32.4′ N		Δλ	2° 44.4′ E
L.D.R.	37° 24.3′ N		λ D.R.	73° 06.6′ W
Δ. L.	° .8′ S			
L.D.R.	37° 23.5′ N	Time Polaris Obs.		
LObs.	37° 31.9′ N	Polaris Obs.		
ΔL. N	° 8.4′ N	Drift in Lat. from Time Dep. .78 m.p.h. Drift in Lat.		

L. N. T. Sun R/S	7 h	10 m	30.0 s
Long. Sun R/S	4 h	52 m	26.4 s
G. M. T. Sun R/S	0 h	02 m	56.4 s
Watch Error	4 h	59 m	54.7 s
W. T. Sun R/S	7 h	03 m	01.7 s
Cor. Bridge	0 h	m	s
W.T.App.Sun R/S	h	m	s
*		h	°
*		h	°
*		h	°
*		h	°
*		h	°
*		h	°

Dip. 15′	19 h	10 m	30.0 s	(10 Bowditch) 25th
R. A. M. O.	18 h	18 m	43.3 s	(Page 2-3 Naut. Al.)
Cor. G. M. T.	0 h	m	00.5 s	(Page 2-3 Naut. Al.)
L. S. T.	18 h	29 m	13.8 s	
L. D.R.	37°	24.3′		
Cor.	1°	07.1′ (Tab. I, Page 107 N. A. use Opp. Sign)		
Polaris h	36°	17.2′ N		
	Z	°		
	Z	°		
	Z	°		
	Z	°		
	Z	°		
	Z	°		

I. C.	+0°	01.2′	
Cor. Tab. I.	−0°	07.1′	
Corr.	−0°	05.9′	
hs.	36°	31.0′	
ho	36°	25.1′	
Corr.	+ 1°	06.8′	(Tab. I, Page 107 N. A.)
Lat.	37°	31.9′ N	
ΔL.	°	04.0′ N	
Drift in L.	°	1.0′ N	
Lat.	37°	36.9′	

C. Tc.	11 h	52 m	30.6 s	
C. C.	− h	12 m	15.3 s	
G. M. Tc.	11 h	40 m	14.7 s	
W. Tc.	6 h	40 m	20.0 s	
W. Err.	+ 4 h	59 m	54.7 s	
Sun R/S W.T.	7 h	03 m	01.7 s	
Polaris W. T.	6 h	45 m	00.0 s	
Δ W. T.	− h	18 m	01.7 s	
N.A. Pages 2-3 Cor. Δ W.T.	− h	00 m	03.0 s	
Sun R/S L.S.T.	13 h	29 m	13.8 s	
Polaris L.S.T.	13 h	11 m	09.1 s	
W. T.	6 h	45 m		
ΔW. T.	1 h	15 m		
W. T.	8 h	00 m		a.m. p.m.

Civil Date

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	Com. C °	Dev. °	Var. °		Error °	Tr. C. °	Dist. ′	ΔL ′	p ′

Lat. ° ′	λong. ° ′	
ΔL. ° ′	Δλ ° ′	
L.D.R. ° ′	λ D.R. ° ′	
Δ. L. ° ′		
L.D.R. ° ′	Time Polaris Obs.	
L.Obs. ° ′	Polaris Obs.	
ΔL. ° ′	Drift in Lat. from Time Dep.	
	m.p.h. Drift in Lat.	

L. M. T. Sun ^R_S h m s	h m s (10 Bowditch) (VI N. A.)		C. Tc. h m s
Long. Sun ^R_S h m s	R. A. M. ⊙ h m s (Page 2-3 Naut. Al.)		C. C. h m s
G. M. T. Sun ^R_S h m s	Cor. G. M. T. 0 h m s (Page 2-3 Naut. Al.)		G. M. Tc. h m s
Watch Error h m s	L. S. T. h m s		W. Tc. h m s
W. T. Sun ^R_S h m s	L. D.R. ° ′		W. Err. h m s
Cor. Bridge 0 h m s	Cor. ° ′ (Tab. I, Page 107 N. A. use Opp. Sign)		Sun ^R_S W.T. h m s
W.T.App.Sun ^R_S h m s	Polaris h ° ′	I. C. 0° ′	Polaris W. T. h m s
* h °	Z °	Cor. Tab. I.– 0° ′	Δ W. T. h m s
* h °	Z °	Corr. – 0° ′	N.A. Pages 2-3 Cor. Δ W.T. h m s
* h °	Z °	hs. + ° ′	Sun ^R_S L.S.T. h m s
* h °	Z °	ho ° ′	Polaris L.S.T. h m s
* h °	Z °	Corr. ° ′	(Tab. I, Page 107 N. A.)
* h °	Z °	Lat. ° ′	W. T. h m
		ΔL. ° ′	
		Drift in L. ° ′	ΔW. T. h m
		Lat. ° ′	W. T. h m A. M. P. M.

THESE FORMS CAN BE PURCHASED (IN PADS OF 25) FROM YOUR DEALER OR BY MAIL FROM J. J. MCCRACKEN, NORFOLK, VA.

CHAPTER 4

McCracken Form 4

Star Sight—Aquino—H. O. No. 200

McCracken Form 4—This form is for use in solving the Astronomical Triangle in the case of Stars and Planets by the use of Aquino Tables, H. O. No. 200. It provides for getting the Compass Error, identifying the star or planet from its altitude and azimuth, and where more than one star is observed for getting the G.S.T. from the G.S.T. of the first star, by applying the difference of the watch times of the observations. Since this is a line of position observation the exact D.R. position is of little practical importance, so that the D.R. position of Sun R or Sun S according as it is a morning or evening observation will be quite sufficient. Provision is made for moving the line of position by Table 2 Bowd. for the difference between observed and computed altitudes and for course and distance to bring the line up to some other time of the day.

The precepts printed at the bottom of each form will be found a great labor saver and convenience.

The Star's or Planet's Local Hour Angle and Longitude of Position Point A—The watch error is found by applying the chronometer correction to the chronometer time of comparison, which gives the G.M.T. of comparison, and the difference between G.M.Tc. and W.Tc. gives the watch error. According to our practice as the Navigating Watch must be set to either L.A.T. or the L.M.T. of some nearby Standard Meridian, when the Longitude is East we subtract G.M.Tc. from W.Tc. to get the W. Err., adding twelve hours to W.Tc. when less than G.M.Tc. so that the watch should be fast on G.M.T.; when the Longitude is West we subtract W.Tc. from G.M.Tc. to get the W.Err., adding twelve hours to G.M.Tc. when necessary, so that the watch should be slow on G.M.T.

The W.Err. and W.To, Watch time of observation, are combined; when W.Err. is fast it is subtracted from W.To. and when slow added to W.To. to get the G.M.T. of observation, G.M.To. If G.M.To. is p.m. the local date and the number of hours as obtained are used or written, but if the G.M.To. is a.m. the local date of the previous date is used and twelve hours added to the number of hours obtained. By adding the Right Ascension of the Mean Sun, at G.M.Noon of the Greenwich Astronomical date, the correction for the mean time interval from G.M.Noon, and the G.M.To., we get the G.S.T. of observation, remembering when the summation is greater than twenty four to subtract twenty-four from it before writing it down.

The Right Ascension of the Star or planet is obtained from the Nautical Almanac. When greater than G.S.To., the G.S.T. is subtracted from R.A.* and G.H.A. is marked minus the star being East of the Greenwich Meridian and when R.A.* is less than G.S.To. the G.H.A.is marked plus since it is west of the Greenwich Meridian. Since when the Longitude is West, Greenwich is East of the Local Meridian, and vice versa, for combining with the Star's G.H.A. to get the Local Hour Angle of the Star, t D.R., we mark West Longitude minus and East Longitude plus and then combine the two in accordance with their signs. The Star's Local Hour Angle may be greater than six hours or 90 degrees, so that under it we provide for subtracting it from twelve hours before converting it into degrees, minutes and seconds, as the tables only give hour angles up to 90°, and the t is measured from the Meridian of lower culmination backward towards the celestial meridian of the star. The precepts at the bottom of the page take care of this variation so all we need to do practically is to subtract the first t from twelve hours and convert into degrees, minutes, and seconds. The t or final t that we obtain from the tables is written in under the t by D.R. and the difference between the two written down as Δt. Since our Longitude has been assumed, we must now change the first assumpsion so that t by D.R. and tA will be equal, and by an amount equal to Δt. Under Δt we write in the Longitude by D.R. and it is evident that we must either add or subtract Δt to get Longitude corresponding to tA. If t by D.R. is less than tA we must make t by D.R. greater otherwise it must be made less so that we go back to the difference between G.H.A. and Long. by D.R. expressed

in hours, minutes and seconds and determine whether to make Long. by D.R. greater or less to make t by D.R. equal to tA. When t is greater than six hours do not over look that there are two t's by D.R. The correct handling of this changing of the assumed Longitude is the pit fall for the beginner in the use of the Aquino method. If you apply Δt wrong you double the error or mistake. Retrace the steps if necessary, if the hour angle is greater than six hours subtract the tA from 12 hours and apply it to the G.H.A. The Longitude of position A is only different from Longitude by D.R. by an amount equal to Δt; t by D.R. and tA always have the same sign, so that you can always catch a big mistake such as adding tA to G.H.A. when it should have been subtracted When the t is less than six hours the first and second tD.R. in the form are the same and it is not necessary to fill in the second one. My practice is to retrace the steps, that is, I determine whether t by D. R. in degrees and minutes must be greater or less to equal tA and mark in front of it the mathematical sign greater or less than mark the t by D.R. greater or less and finally the Longitude by D.R. greater or less and if it comes out greater, add Δt, if less, subtract, which will be shown more clearly in the examples that will be worked out. The form provides for applying the G.H.A. and tA but when the H.A. is greater than 90° you subtract the tA as obtained from the table from 180° before combining it with the G.H.A. in degrees and tenths of minutes of arc to get λA.

Star Identification—Fill in the observed altitude and azimuth of the star or planet. The azimuth is measured from the North and South points of the horizon to the Eastward and Westward and when from the point of the horizon the same name as the Latitude is less than 90° and when measured from the opposite point greater than 90°. When East the Hour Angle is negative, when West positive. The azimuth is reduced to True Bearing by applying the approximate compass error to the observed bearing. It will usually be sufficiently accurate for identification if the observed azimuth is correct to the nearest twelve degrees.

Enter the Aquino tables with the ho and Zo as arguments and find their nearest coincidence picking out C to the nearest whole degree. From the precepts given at the bottom of the form there are two conditions under which Z may be less or greater than 90°. From the observed azimuth we know immediately whether Z is greater or less than 90°. When Z is less than 90° if C plus L is less than 90°, then b equals C plus L, if C plus L is greater than 90°, then b equals 180° minus C plus L, from the method of determining b, the precepts tell whether Declination is the same name and whether t is greater or less than six hours or 90°. When Z is greater than 90°, b is the difference between C and L and as in this case t is always less than 90°, when L is greater than C the Latitude and Declination are of the same name, and when C is greater than L, the Latitude and D are the Opposite in name. From b, in the same "a" column in the tables we pick out d and t. By applying the t to the approximate L. S. T. rememberig that L.S.T. minus t equals the R.A.* and that when t is greater than 90° we subtract the t found in the Tables from 180° we get R.A.* By examining the R.A.* and d given in the Nautical Almanac for the Stars and Planets, as the large stars are not very close together, little difficulty is experienced in determining the name of the star or planet. The planets move about during the year so that the beginner may get the planets mixed up with some of the very bright stars, but as stars twinkle and the planet light is steady this may be a help. For instance in the Northern hemisphere you may mistake Sirius for Venus or Jupiter, Saturn for Aldebaron, and Mars for Arcturus. If you use McCracken's Star Identification Protractor and put the planet markers on the star chart for Sun R or Sun S the nearness of a planet to a large star will be readily seen and warn you to be sure of which you observed. In cloudy weather, especially at Sun S, Stars and Planets frequently show themselves at brief intervals when the Constellations are not visible, so that the possibility of mistaking a planet for a star is quite probable.

Computed Altitude and Azimuth—Fill in 2nd column from the right in the form after d the Declination, as obtained from the Nautical Almanac, corresponding to the G.M.As.T. of the observation and mark it N or S according as it is marked plus or minus in the Naut. Al. Opening up the Aquino tables and looking at the bottom we see angles corresponding to d to the nearest 30′ of arc. We turn to the column having the nearest d to the d of the body and run up the left hand vertical column until we come to an angle nearest to the t by D.R. and going horizontally across the page to the vertical column containing the d at the bottom we pick out the angle from the column marked "a" at the bottom. This gives the approximate value of the "a." in the astronomical triangle to be solved. Turning to the vertical column which has "a" equal to this angle we will be close to the coincidence of d of the body and t by D.R.

By examining the angles in the d and t columns on either side of the approximate "a" we quickly determine the value of "a" giving d and t closest to our d and t desired. It matters little whether we get quite the nearest one or not as the difference between the computed and observed altitudes will bring the line of position where it belongs. In view of determining the Compass Error from the computed azimuth, compared with an observed one taken within a few minutes of the observation, it is desirable to get the closest coincidence. Since the declination is fixed corresponding to any particular G.M.T. which is also fixed, in order to save interpolation we interpolate for d. Fill in after "a" the value of "a" in the column you have decided to use and pick out the nearest d less than our d, writing it in after d′ in the form and also after t′ the corresponding value of t given in the tables. After b′ write in the value of the angle on the same horizontal line in the extreme left hand vertical column. Subtract d′ from d giving Δd which ordinarily will be less than 60′.

On the same horizontal line with d′ in the table under 60′ / Δ column is the multiplier for interpolating for the additional minutes of b, and we put this in the form after the first multiplication sign after Δd, which by multiplying Δd by it gives the number of additional minutes to add to b′ to get b corresponding to the body's d. Multiplying the result by the number after t′ on the same horizontal line after it gives the number of minutes to be added to t′ to get t corresponding to the body's d or tA given in the form which means Hour Angle of Position Point A. The addition is performed as indicated in the form giving b and tA. From the precepts given at the bottom of the page we determine how to combine b and the Latitude by D.R., and since our Latitude may be varied for computation, we fill in an assumed Latitude as near D.R. as possible, but so as to make C come out an even number of degrees to save interpolation. The C is found in the Right hand vertical column and is run from the bottom towards the top, run over horizontally from the value of C to the "a" column and pick out under h column the computed altitude and from Z column the computed Azimuth putting them in the form after hc and Zc. When Z is less than 90° the azimuth is reckoned from the elevated pole, and when greater than 90° from the depressed pole, and should be marked N or S, so many degrees East or West.

Observed and Computed Altitudes—The I.C., if given, Cor.Tab.1 H.O.200, are combined to give Corr. which applied to the sextant altitude, hs, gives the observed altitude, ho. The difference between ho and hc is obtained and put down as Δh, it being now necessary to move the Position Point A or line of position towards the body if ho is greater, and away from the body if ho is less than hc, the direction of the body from position point A being its azimuth or bearing. We accordingly fill in position point A by its Latitude and Longitude and move the point Δh miles towards or away from the body as the case may be, filling in after Dir. the way we move it. From this we get position point B which establishes a point on the line of position of the observer, the line running at right angles to the azimuth, the direction being written in after Dir.Line. Factor F is the number of minutes change of Longitude on the line for a change of one minute of Latitude and may be found from Table 47 Bowd. or by Table 2 Bowd. in the following way. With direction as angle find Dep. corresponding to 1′ Lat., turn to angle equal to the Latitude of the Line and pick out from Dist. column the number in the Lat. column equal to the Dep. found corresponding to change of one minute of Latitude on the line of position. The form still further provides for running the line up or back to some other time or observation.

Compass Error—The Form provides for obtaining the compass error from the observed bearing at the time the observation was taken, it further providing for taking it from the Pelorus. The steps are so simple that by following the form and marking the Error, Variation, etc., no diffculty should be experienced in following it and will be explained more in detail under McCracken Form 5.

Aquino Tables—The Aquino Tables are tables for solving the Astronomical Triangle by dividing it into two right angled spherical triangles. The perpendicular is let fall from the body's projection on the celestial sphere to the celestial meridian of the observer, "a" being the length of the arc from the body's projection to the celestial meridian. Due to the fact that the relationship existing between a,d,t, and b of one triangle is exactly the same as a,h,Z, and B of the other we need only solve one triangle, for by marking column b as column B we can mark d as h and t as Z. Since "a" is common to both triangles, if for a certain value of "a" we make a table for values of b, zero to ninety degrees, the same table will do for the same value of "a" and values of B zero to ninety degrees. C is merely an arbitrary angle assumed to be always 90°−B, therefore is put over on the right hand side, beginning at zero at the bottom and running to ninety at the top, that is opposite to B in the left hand column. Once b is determined the value of B is only a question of combining Latitude and b according to whether the perpendicular let fall

from the body's projection intersects the celestial meridian, across the pole from the observer, between the observer and the elevated pole or between the observer and the depressed pole. Due to the immense size of the earth compared with any particular locality on its surface, and the large distances the bodies are from the earth, circles of altitude may be assumed to be straight lines at right angles to the bearing of the body; so that if we locate the position of some point on the circle for a particular locality, it may be assumed that all the points on the circle within sixty miles will be on a straight line through the position point located, and running in a direction at right angles to the bearing of the bodies. The line of position is very frequently known as the Sumner Line of Position, although Sumner located the line by two position points by their Latitudes and Longitudes and connected the two points extending the line on either side of the position points.

It should be noted, that the value of t for the same value of d, and the value of Z for the same value of h, increase in value the larger the value of "a." The realization of this saves time in the use of the table, for then, you can cut out finding the approximate value of "a" and open the table, look quickly for the value equal to d or h, and if the corresponding value of t or Z is less than your t or Z you know the value of "a" must be greater and you start turning to a greater angle of "a". After a little practice you can generally find the coincidence in about four turns of the pages which will save at least one half a minute in working out a sight. Remember the advantage of Aqunio is to save time and labor, the relative advantage of the following methods in time are as follows, Aquino 8 minutes, St. Hilaire, 14 minutes, and Time Sight or Sumner Method 22 minutes. In working out three stars Aquino 24 minutes, St. Hilaire 42 minutes, and Sumner Method 66 minutes. These times include putting the lines on the chart and crossing them. Aquino is well worth the trouble to learn, it is at present writing the best Practical Astronomical Navigation Method available to the Modern Navigator. Do not try for speed at first get accuracy, as you will probably make numbers of mistakes especially in changing your assumed Longitude to the Longitude of Position A. When making port in cloudy weather not knowing your position except by D.R., I have produced a line of position on the chart by the Aquino Tables in four minutes from the time I took the observation, a performance I cannot duplicate by any other method I have ever heard of, and I have tried most all the methods that get any kind of practical results.

EXAMPLE

9 May 1920, p.m. W.T. 7-13-02, observed the altitude of a large star or planet 25° 20.8′ by sextant, bearing about 130° p.s.c., Compass Error 5° 00′ W, Chronometer time of comparison, C.Tc., 12-14-00, Chronometer correction, c.c., 0 m 37 s fast on G.M.T., watch time comparison, W.T.c, 7-32-49. The approximate position Lat. 37° 15′ N, Long. 71° 30′ W. Compass Course 89°, speed 11 knots. Identify the star or planet, find the line of position for 8:00 p.m. and the Deviation, Var. 10° 00W, Dep 39′.

The first step is to get the G.M.T. of the observation. From the comparison of the watch with the chronometer we get the watch error to be 4-40-34 slow on G.M.T., so that adding this to the W.T. of the observation the G.M.To. is 11-53-36, and since the W.To. is p.m. and slow and the G.M.To. less than twelve hours the G.M.To. is p.m. Since the G.M.To.is p.m. G.As.M.T. is the same as G.M.To. From the N.A. page 2-3 we get the R.A.M.O. at G.M. Noon 9 May 1920, and correction for the time past Noon, which applying to G.M.To., gives G.S.T. 15-03-32.4. The approximate Longitude is 71°30′ = 4 h 46m 00 s so that applying this to G.S.T. gives L.S.T. 10 h 17 m 32.4 s. Under Star Identification fill in ho 25° 20.8′ and Zo S 55° E = 125°, the True Bearing of the observed body. We enter the Aquino tables and find under a = 48° and C = 51°, h 24° 54′ and Z 55° 01′, so that we fill in C as 51° and since Z is nearer the South or depressed pole, it is greater than 90°, and b is the difference between L and C and since C is the greater b = C − L = 14° and L and d are opposite name therefore the d of the body is South or minus. From b = 14° and a = 48° we find for d 9° 19′ and t 48° 51′ less than ninety degrees. Applying the t to the L.S.T. we get the Right Ascension of the body to be 13-32-56.4, and the d is 9° 19′. It must be remembered that we have used approximate values in working out d and t therefore we will only get approximate t and d but close enough to tell which star. Looking in the N.A. page 94-95 we find the nearest star is Spica R.A., about 13-21 and d 10° 45′ S, therefore it might have been Spica. Before deciding that the body was Spica it is a good plan to look at the Planets for 8 May 1920. Saturn, Jupiter, and Venus are immediately eliminated but we find for Mars R.A. 13-32-17 and d 8° 48.1′ you are therefore certain that you have either observed Mars or Spica and as Mars comes the closest you can

be safe in assuming it to be Mars. With the exception of Arcturus which also is redish in appearance, Ruddy Mars, is quite easily distinguished from Spica which in comparison to Mars is a small star and identified from the gaff of the spanker. We proceed on the assumption that Mars was observed and for its R.A. 13-31-43 and d 8° 46.3′ S. The G.H.A. is plus 1-31-49.4 as G.S.T is greater than R.A.* and since Longitude is W it is marked minus so that t by D.R. is minus 3-14-10.6 = 48° 32.7′ which it should be when the body bears East so that your bearing helps to check the work. The value of "a" found in the identification of the body will be within a couple of degrees of the one you will use in solving the triangle so that all the work of identification is not lost. We look for coincidence of d and t by D.R. and find in this particular it is under the same "a" we used in identifying the star and picking out the nearest value d less than Declination of the body we have for d′ 8° 39′, b′ 13° 00′, t′ 48° 44′, and the multipliers 1.5 and .12. Subtracting d′ from d gives Δd 7.3′ which multiplied by 1.5 gives 11.0′ which added to b′ gives for b 13° 11′, continuing the multiplication of 11.0′ by .12 we get 1.3′ which added to t′ gives tA 48° 45.3′. Since L and d are opposite name, C = L plus b in which case in order that C may be an even number of degrees the minutes of LA must be equal to, sixty minus the minutes of b, 60−11=49′. The L must be as near 37° 15′ the approximate Latitude as we can get it, so that we assume for LA 37° 49′ giving for C the value 51°. For C = 51°, a =48°, we find hc 24° 54′ and Zc 55° 01′ which as Z is greater than 90° gives S 55° 01′ E or 124° 59′.

Applying the G.H.A. reduced to degrees, minutes, and seconds, to tA adding the two as the body is West of Greenwich and East of the observer, we get Long. of A 71° 42.7′ W. We may also add Δt to the Long. by D.R. and get 71° 42.6′ W the difference of .1 in the minutes being due to method of handling .05′, the correct result in both cases would be 71° 42.65′, these small discrepancies are of no value to the Practical Navigator.

Δh is 18.8′ and since ho is greater than hc we move the line towards the body or in the direction 125° which is South and East. Moving by use of Table 2 Bowd. ΔL 10.8′ S and Diff. Long. 19.3′ E, remembering that Dep. has to be multiplied by sec L to get Diff. Long. so that for Position Point B we get Lat. 37° 3[illegible].[illegible] N and Long. 71° 23.4′ W, and direction of the line 125° − 90° = 35°. Since the observation was taken at 7-13-02 p.m. we must move it in the direction of the True Course, and for run of 47 m which as the speed is 11 knots will be 8.8 miles. The Compass Error being 5° W and Compass Course 89°, the True Course is 84°, so that we move Position Point B 8.8′ in Direction 84°, getting Lat. 37° [illegible]′ N, Long. 71° 12.4′ W for Position Point P the direction of the line remaining 35°. By drawing a line through the Lat. and Long. of Position Point P in direction 35°, we will have our line of position run up to 8:00 p.m. which by crossing with some other observation Line of Position run up to 8:00 p.m. will give observation Position at 8:00 p.m. Due to the small time interval, Practical Navigators, seldom use correction for set and drift in doing this, but many cross the lines before moving them to another position. When observations of two or more stars or planets are taken it frequently happens that there is an appreciable run, during the time intervals between observations, in which case each line is moved to the time of observation of one of them, preferably the last one taken, and the lines crossed on a Mercator Chart or Plotting sheet. As a rule the cross is a small triangle, or several of them depending on the number of stars observed. The middle of the figure formed by the intersection of the lines is taken as the fix, and you should from the fix with a radius equal to two miles be able to describe a circle which should contain all the intersections. The Compass Error is found from the difference between the Computed or True Z and the observed Z and has been sufficiently explained in previous chapters.

PRACTICAL EXAMPLES

(49) At W.To. 7-13-22 p. m. 11 May 1920, observed hs of star 39° 16′ bearing 115° p.s.c., Comp. Err. about 19° W, dip 39′, approximate position Lat. 38° 30′ N, Long. 61° 30′ W., W. Err. 4-08-10 slow G.M.T.

Required the name of the star, the line of position by the method of Aquino, and the Compass Error.

(50) 16 May 1920, morning twilight, approximate position Lat. 40°, 00′ N, Long. 39° 15′ W, observed two stars as follows:

W.T. 3-53-25 a.m., hs 9° 20.5′, bearing 149° p.s.c.

W.T. 3-55-30 a.m., hs 17° 33′, bearing 26°, p.s.c.

The dip was 39′, estimated compass error 15° W, W Err. G.M.T. 2-52-04 slow.

Required the identification of the stars by the method of Aquino and the astronomical fix.

(51) 5 June 1920, p.m., Lat. by D.R. 42° 45′ N, Long. D.R. 3° 55′ E, dip 39′, W. Err. 1-03-48 fast G.M.T. W.T. 8-56-37 p.m. observed Mars hs 38° 40′, and W.T. 8-57-54 p.m. observed Jupiter hs 33° 43′. Required the astronomical fix.

(52) 14 June 1920, p.m., approximate position Lat. 36° 00′ N, Long. 38° 30′ W, dip 39′, W. Err. 2-30-06 slow G.M.T., obtained the following observations:

Mars, W.T. 7-43-37, hs 44° 40.5′; Jupiter, W.T. 7-45-~~50~~ 30, hs 33° 46.5′; Arcturus, W.T. 7-47-22, hs 69° 23.3; Vega, W.T. 7-52-38, hs 29° 39′; and Polaris, W.T. 7-59-13, hs 35° 01.8′. Required the lines of position and the astronomical fix at time of Polaris observation. Speed of ship 10 knots, course 270° true.

Note:—In solving problem 52, each line should be run up to the time of Polaris observation, when the advantage of using a traverse table to move the lines becomes apparent. By careful working of this problem and plotting on the plotting sheet and then studying the results obtained it will be an invaluable lesson. The observations were taken at sea in the ordinary practice of Navigating a ship making a passage from Genoa, Italy to Hampton Roads, Va., and nothing of the Berth Deck variety of sight is included in it. The intersection is not a point, but shows what you may expect from crossing more than two astronomical lines of position at sea from observations carefully taken, and times accurately marked. No index correction is given as the sextant had none that could be observed. The labor saved by standardizing your Navigation and the use of printed forms is at once apparent. It is the only way to obtain the best practical results, and well worth the financial expenditure, to your country, your owner, and yourself.

McCRACKEN FORM 4

STAR SIGHT (AQUINO) H. O. No. 200

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Civil Date

I. C.	0° '	d+	8° 46.3'	a	48° 00 '				C. Tc	12 h 14 m 00.00 s
Cor. Tab. 1	0° 8.0'	d'−	8° 39.0'	b'	13° 00.0'	t'	48° 44 '	fast	C. C.	0 h 00 m 37 s
Corr.	0° 8.0'	Δd	° 7.3' × 1.5		= 11.0' ×	12	= 1.3'		G. M. Tc	12 h 13 m 23 s
hs	25° 20.8'			b	13° 11.0'	tA	48° 45.3'		W. Tc	7 h 32 m 49 s
ho	25° 12.8'			L. A.	37° 49.0'	G. H. A.	22° 57.4'	1st. * W. T.	W. Err.	4 h 40 m 34 s
hc	24° 54.0'	Zc	s 55° 0.01' E	C	51° 00.0'	λA.	71° 42.7'	W. To	W. To	7 h 13 m 08 s
Δh	° 18.8'	L A	37° 49' N	λA.	71° 42.7' W			A. W. T.	G. M. To	11 h 53 m 36 s
Δh	° 18.8'	ΔL.	° 10.8' S	Δλ	19.3' E	Dir.	125°	1st. * G. S. T.	R. A. M. ⊙	3 h 07 m 59.1 s
Factor F	.88'	L B	37° 3[illegible]' N	λB.	71° 23.4' W	Dir. Line	35°	Gr. Δ W. T.	Cor. G. M. To	0 h 01 m 57.3 s
Dist. To	8.8'	ΔL.	° .9' N	Δλ	° 11.0' E	Tr. C.	84°			
W. T.	h m A.M. P.M.	L P	37° [illegible]' N	λP.	71° 12.4' W	Star Identification			G. S. To +	15 h 03 m 32.4 s
									R. A. * −	13 h 31 m 43.0 s
Obs. Zo.	130° 00'					ho	25° 20.8'	Zo s55° E	*G. H. A. +	1 h 31 m 49.4 s
Zc.	124° 59'					C	51° 00.0'		λD. R. −	4 h 46 m s
Err.	5° 01'					L. D. R.	37° 00.0'			
Pel. H.	° '					b	14° '		tD. R. −	3 h 14 m 10.6 s
Tr. H.	° '					d	9° 19.0' S		tD. R. −	h m s
Comp. H.	° '					t	48° 51 '			
Comp. Err.	5° 01' W					t	° '		tD. R. −	48° 32.7'
									tA −	48° 45.3'
Var.	10° 00' W					t	−3 h 15 m 24 s			
						L. S. T.	10 h 17 m 32.4 s		Δt −	° 12.6'
Dev.	4° 59' E								λD. R. −	71° 30.0' W
S. H.	89° 00'					R. A. *	13 h 32 m 56.4 s		λA −	71° 42.6' W

L and d same name	t Less	than 90°	L Less than b,	C = b − L	Z Less	than 90°	b = C + L
L and d same name	t Less	than 90°	L Greater than b,	C = L − b	Z Greater	than 90°	b = L − C
L and d same name	t Greater	than 90°		C = 160° − (L + b)	Z Less	than 90°	b = 180 − (L + C)
L and d Opp. name				C = L + b	Z Greater	than 90°	b = C − L

McCRACKEN FORM 4

STAR SIGHT (AQUINO) H. O. No. 200

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Civil Date

I. C.	0° ′	d	° ′	a	° ′				C. Tc	h m s
Cor. Tab. 1	0° ′	d′	° ′	b′	° 00.0′	t′	° ′		C. C.	h m s
Corr. −	0° ′	Δd	° ′ ×		= ′ ×		= ′		G. M. Tc	h m s
hs	° ′			b	° ′	tA	° ′		W. Tc	h m s
ho	° ′			L. A.	° ′	tA	° ′	1st. * W. T.	W. Err.	h m s
hc	° ′	Zc	° ′	C	° 00.0′	G. H. A.	° ′	W. To	W. To	h m s
Δh	° ′	L A	° ′	λA.	° ′	λA	° ′	ΔW. T.	G. M. To	h m s
Δh	° ′	ΔL.	° ′	Δλ	° ′	Dir.	°	1st. * G. S. T.	R. A. M. ⊙	h m s
Factor F	′	L B	° ′	λB.	° ′	Dir. Line	°	Cor. Δ W. T.	Cor. G. M. To	0h m s
Dist. To	′	ΔL.	° ′	Δλ	° ′	Tr. c.	°		G. S. To +	h m s
W. T. h m A. M./P. M.		L P	° ′	λP.	° ′	Star Identification			R. A. * −	h m s
Obs. Zo.	° ′					ho	° ′	Zo °	*G. H. A.	h m s
Zc.	° ′					C	° ′		λD. R.	h m s
Err.	° ′					L. D. R.	° ′		tD. R.	h m s
Pel. H.	° ′					b	° ′		tD. R.	h m s
Tr. H.	° ′					d	° ′		tD. R.	° ′
Comp. H.	° ′					t	° ′		tA	° ′
Comp. Err.	° ′					t	° ′		Δt	° ′
Var.	° ′					t	h m s		λD. R.	° ′
Dev.	° ′					L. S. T.	h m s		λA	° ′
S. H.	° ′					R. A. *	h m s			

L and d same name	t Less than 90°	L Less than b,	C = b − L	Z Less	than 90°	b = C + L
L and d same name	t Less than 90°	L Greater than b,	C = L − b	Z Greater	than 90°	b = L − C
L and d same name	t Greater than 90°		C = 180° − (L + b)	Z Less	than 90°	b = 180 − (L + C)
L and d Opp. name			C = L + b	Z Greater	than 90°	b = C − L

THESE FORMS CAN BE PURCHASED (IN PADS OF 25) FROM YOUR DEALER OR BY MAIL FROM J. J. McCRACKEN, NORFOLK, VA.

CHAPTER 5

McCracken Form 5

Sun Sight—Aquino—H. O. No. 200

McCracken Form 5—This form is for use in solving the Astronomical Triangle, by an observation of the Sun and the use of the Aquino Tables, Table VI, H.O. 200. It is exactly the same as McCracken Form 4 except the Sun needs no identification, and the time found is the Local Apparent Time.

The Local Hour Angle of the Sun—The Watch Error is found by a comparison with the chronometer, and from the W. Err. and Watch Time of observation the G.M.T. of the observation is obtained. From the Nautical Almanac we get the Sun' Declination and the Equation of Time, remembering that these elements are given for G.M.As.T., and that when it is a.m. G.M.T. we must add twelve hours and use the previous day's date. The Eq. t. is applied to the G.M.T. in accordance with the sign given in front of it in the N.A., giving us G.A.To. of the observation. When the Longitude is East add, when West subtract it from G.A.To. to get the L.A.To. of the observation. This assumed Longitude need not be closer than 1°, but when Compass Error is to be determined from an observed bearing of the Sun at the time of observation, it is desirable to get the Longitude to the nearest 15′ of arc.

In the Aquino method this L.A.To. must be converted into degrees, and tenths of minutes of arc, East or West of the Meridian, and under certain conditions may be greater than six hours. Under our practice of using a Navigating Watch set to L.A.T. or L.M.T.of some nearby Meridian when the W.T. is p.m., L.A.T. will be p.m. and vice versa. The form provides a space for subtracting L.A.To. from twelve as in a.m. observations after 6:00 a.m. and p.m. observations after 6:00 p.m., this H.A. is marked t by D.R. following the same practice as in Form 4. The H.A. as obtained from the tables, tA, is applied to t by D.R. and Δt obtained, which we must either add or subtract from Longitude by D.R. or assumed. By retracing the steps we find out whether the assumed Longitude must be made greater or less so that t by D.R. will be the same as tA.

Position Point and Direction of the Line of Position—Longitude is found of position point A by applying Δt to the Longitude by D.R. or Assumed Longitude. The precepts are exactly the same as in star sight and from t by D.R. and Declination we find d′, a, b′, Δd, b, and tA as in the case of a star. This is another advantage of the method, once t by D.R. is obtained the process is identical whether the observed body be Sun, Moon, Star, or Planet. The time of day makes no difference, the only variation is in finding the H.A. from the W.T. of the observation and this variation is very little. We get the computed h and Z and move the line to position point B which is a point on the line of position whose direction is at right angles to the bearing or azimuth. Fractor F is found as in the star line.

Compass Error and Deviation—The comparison of an observed bearing of the Sun with its computed bearing at the same time is the Practical Method of obtaining the Compass Error at sea. With a daily good comparison with the Sun, you will seldom need to take a bearing of a star for compass error. A rough bearing of a star is essential for identification quite frequently. The Observed Azimuth and Zc are compared and their difference is the Compass Error which is marked East and plus or West and minus according to the rules given in Chapter E. It is best to use the 0°-360° method, for then if Zc is greater than Zo the Compass Error is plus and East and if Zc is less than Zo the Compass Error is minus and West. The form provides for using the Pelorus but if taken direct from the compass you fill in Comp. Err. equal to Err. The Variation is taken from the Pilot Chart or Variation Chart and is combined with the Comp. Err. to get Deviation. When they both have the same sign Dev. is their difference and takes the name of Comp. Err. when Comp. Err. is greater than Var., otherwise opposite sign or name to Comp. Err. When they have different signs or names Deviation is their sum and takes the name or sign of the Comp. Err. What is fundamental here is that Var. plus Dev. shall be equal to the Compass Error, due regard being paid to signs or letters.

EXAMPLE

11 May 1920, a.m. W.To. 9-58-30, sextant hs Sun's Lower Limb 55° 52.5′, W. Err. 4-08-04 slow on G.M. T., Compass Bearing Sun 135° p.s.c., Compass Course S 82° E p.s.c., speed 9 knots, watch set to L.A.T. Required the line of position run to L.A.Noon and the Deviation, the Var. by chart 15° 30′ W. Lat. D. R. 38° 09′ N, Long. D.R. 63° 15′ W. Dip 26′.

Applying the W. Err. to W.To. the G.M.To. is 2-06-34 p.m. 11th. From N.A. page 14, 11 May 2 hours, d 17° 53.7′ and Eq. t. plus 3 m 45.7s, and since the correction for .1 h is inappreciable we do not in this case interpolate. Applying the Eq. t. the G.A.To. is 2-10-19.7 and subtracting the Longitude as it is West, L.A.To. is 9-57-19.7 a.m. which subtracted from 12 hours gives 2-02-40.3 to Meridian of the Local Meridian of the observation, converting into degrees and minutes gives 30° 40.1′ as t by D.R.

Opening the Aquino Tables to d 18° the nearest whole degree to d of Sun and running up the t column. at the bottom to 31° the nearest whole degree to t by D.R. we read off from "a" column at the bottom 29° 20′ which is the approximate value of "a" giving the d and t by D.R. coincidence. Turning to "a" at the top to values 29° and 29° 30′, it will be seen by inspection that 29° for "a" gives the closest coincidence. Running down the 29° column we find at b = 20° the closest coincidence for "a" value of d less than the d of the Sun. We accordingly from the table with a = 29° and b = 20° get the following, a = 29°, b′ = 20°, d′ = 17° 24′, t′ = 30° 32.0′, and the two multipliers 1.15 and .17 filling them in the form as shown. Multiplying Δd by the first multiplier gives the number of minutes to add to b′ to get value of b corresponding to the Sun's d. Further multiplication by the second multiplier gives the number of minutes to add to t′ to get tA. Putting tA under t by D.R. and getting their difference gives Δt = 02.3′ under which we fill in the Long. by D.R. to which we must either add or subtract Δt. It is evident that to make t by D.R. = tA the value of t by D.R. must be less, therefore L.A.To. must be greater, therefore the Long, by D.R. must be less, we accordingly subtract Δt from Long. by D.R. giving for Longitude of Position Point A 63° 12.7′ W.

L and d have the same name both being North, t is less than 90°, and L is greater than C from which we get C = L − B, Z greater than 90°, and the body is South and East. The value of C must come out in even number of degrees, LA must be as near 38° 09′ as possible, and C = L − B, we know then that the minutes of L and b must be the same, so we assume L as 38° 34.2′, which gives C = 18°.

With a = 29° and C = 18°, we find hc 56° 17′ and Zc 60° 52′ South and East, or Zc 11 9° 08′. Comparing Zo and Zc we get compass error 15° 52′ W, and Deviation 0° 22′ W.

hs is corrected by Table 1 H.O. No. 200, giving ho 56° 02.8′, which compared with hc gives Δh 14.2′ and since ho is less than hc we must move our line or position point A in direction away from the Sun that is 299°. Position Point B then becomes Lat. 38° 41.1′ N and Long. 63° 28.7′ W, and the Direction of the Line at right angles to its bearing, giving Dir. Line 209° or 29°. In moving position points by the Tables do not forget to convert Dep into minutes difference of Longitude. The time interval to Noon is 12-00-00 minus 9-58-30 or 2-01-30 and with speed nine knots, the run is 18.2 miles. We accordingly move Position Point B 18.2′ on S 82°E p.s.c. reduced to True Course, 82°, we get position point P 38° 43.6′ N and 63° 05.5′ W. Through this point draw a line in direction 209° and we have the line of position moved to Noon.

PRACTICAL EXAMPLES

(53) 20 May 1920, a.m., W.To. 7-43-03, sextant hs Sun's Lower Limb 35° 30′, I.C. −1′ 00″, W. Err. 1-24-08 slow on G.M.T., compass bearing S 70° E p.s.c., Compass Course 125° p.s.c., speed 9.1 knots, watch set to L.A.T. of the previous noon. Required the line of position by the method of Aquino run to 8:00 a.m. watch time and the Deviation of the compass. Variation by chart 19° 15′ W, approximate position Lat. 39° 00′ N; Long. 18° 15′ W. Height of eye 36 feet.

(54) 24 May 1920, p.m., W.T. 5-03-28, sextant hs Sun's Lower Limb 22° 57′ 30″, I.C. plus 0′ 30″, W. Err. 0-18-27 fast on G.M.T. compass bearing Sun N 71° W. p.s.c., Compass Course 67° p.s.c., speed 10 knots. Required the line of position run to 8:00 p.m., and the Deviation. Var. by chart 12° 00′ W. Approximate position Lat. 39° 45′ N, Long. 5° 00′ E. Dip 36 feet.

McCRACKEN FORM 5

SUN SIGHT (AQUINO) H. O. No. 200

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Civil Date

I.C.	0° ′	d	17° 53.7′ N	a	29° ′		Obs. Zo	135° 00′	C.Tc.	h m s
Cor. Table +	0° 10.3′	d′	17° 24.0′	b′	20° 00.0′	t′ 30° 32.0′	Zc	119° 08′	C.C.	h m s
		Δd	° 29.7′ ×	1.15	= 34.2′	× .17 = 05.8′				
Corr. +	0° 10.3′						Err.	15° 52′	G.M.Tc.	h m s
hs	55° 52.5′			b	20° 34.2′	tA 30° 37.8′	Pel. H.	° ′	W.Tc.	h m s
				L.A.	38° 34.2′					
ho	56° 02.8′						Tr.H.	° ′	W.Err.	4 h 08 m 04 s
hc	56° 17.0′	Zc	s 60° 52.0′ E	C	18° 00.0′		Comp. H.	° ′	W.To	9 h 58 m 30.0 s
		L.A.	38° 34.2′ N	λA	63° 12.7′ W					
Δh	° 14.2′	ΔL.	° 6.9′ N	Δλ	° 16.0′ W	Dir. 299°	Comp. Err.	15° 52′ W	G.M.To.	2 h 06 m 34.0 s
Δh	14.2′						Var. −	15° 30′ W	Eq. t+	0 h 3 m 45.7 s
Factor F	.70′	L.B.	38° 41.1′ N	λB.	63° 28.7′ W	Dir. Line 209°				
Dist. to Noon	18.2′	ΔL.	° 2.5′ N	Δλ	23.2′E	Tr.C. 82°	Dev.	0° 22′ W	G.A.To.	2 h 10 m 19.7 s
							S.H.	98° 00′	<λD.R.	4 h 13 m 00.0 s
W.T. 12h 00m M		L.P.	38° 43.6′ N	λP.	63° 05.5′ W				>L.A.To	9 h 57 m 19.7 s
									<tD.R.	2 h 02 m 40.3 s
									<tD.R.	30° 40.1′
									tA.	30° 37.8′
									Δt	° 2.3′
									λD.R.	63° 15.0′ W
									λA	63° 12.7′ W

L and d same name	t less than 90°	Less than b,	C = b − L	Z less than 90°
L and d same name	t less than 90°	L greater than b,	C = L − b	Z greater than 90°
L and d same name	t greater than 90°		C = 180° − (L+b)	Z less than 90°
L and d opp. name			C = L + b	Z greater than 90°

SUN SIGHT (AQUINO) H. O. No. 200

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Civil Date

I.C.	0° ′	d	° ′	a	° ′			Obs. Zo	° ′	C.Tc.	h m s
Cor. Table	+ 0° ′	d′	° ′	b′	° 00.0 ′	t′	° ′	Zc	° ′	C.C.	h m s
Corr.	0° ′	Δd	° ′ ×		= ′ ×		= ′	Err.	° ′	G.M.Tc.	h m s
hs	° ′			b	° ′	tA	° ′	Pel. H.	° ′	W.Tc.	h m s
ho	° ′			L.A.	° ′			Tr.H.	° ′	W.Err.	h m s
hc	° ′	Zc	° ′	C	° 00.0 ′			Comp. H.	° ′	W.To	h m s
Δh	° ′	L.A.	° ′	λA	° ′			Comp. Err.	° ′	G.M.To.	h m s
Δh	′	ΔL.	° ′	Δλ	° ′			Var.	° ′	Eq. t	0 h m s
Factor F	′	L.B.	° ′	λB.	° ′			Dev.	° ′	G.A.To.	h m s
Dist. to	′	ΔL.	° ′	Δλ	° ′			S.H.	° ′	λD.R.	h m s
W.T.	h m A.M./P.M.	L.P.	° ′	λP.	° ′					L.A.To	h m s
										tD.R.	h m s
										tD.R.	° ′
										tA.	° ′
										Δt	° ′
										λD.R.	° ′
										λA	° ′

L and d same name	t less than 90°	L less than b,	C = b − L	Z less	than 90°
L and d same name	t less than 90°	L greater than b,	C = L − b	Z greater	than 90°
L and d same name	t greater than 90°		C = 180° − (L+b)	Z less	than 90°
L and d opp. name			C = L + b	Z greater	than 90°

CHAPTER 6

McCracken Form 6

Setting the Watch—Noon Position—Course and Distance Made Good.

Setting the Watch to Local Apparent Noon.—The method of setting the watch to L.A. Noon is not standard, even among the most skilled Practical Navigators, and due to the small variation in altitude of the Sun, for even a five minute interval near Noon, exactness is unnecessary from a Practical Navigator's viewpoint, for after setting the watch further refinement is obtained by finding the Watch Time of L.A.Noon. The old, time worn, practice of waiting for the Apparent Dip of the Sun and striking eight bells by it, has passed into the discard. The bell is properly struck at clock time of Noon and the position obtained for clock time of Noon or some other standard clock time.

To get the Watch Time of L.A.Noon it is necessary to know the Longitude within one minute of time or 15′ of arc, which requires knowledge of the True Course, Speed of the Ship, and change in Longitude corresponding to the speed of the ship. If the ship is steaming to the Eastward the L.A. Noon will be before relative 12:00 M by clock, if steaming to the Westward after 12:00 M by clock, so steaming East we set the clocks ahead, and steaming West set the clocks back, steaming East the length of the day is less than 24 hours, steaming West the length of the day is greater than 24 hours.

Find the Watch Time interval from time of Departure to relative 12:00 Noon by watch, multiplying this interval by the rate of change of Longitude and convert into time, then apply the error of the watch on L. A. T. at time of Departure to this time interval, using the result as the approximate amount the time is to be changed. If steaming East subtract this amount from the Watch Time Interval from Departure to relative 12:00 M, and if steaming West add it to the Watch Time Interval, making approximate Watch Time of L.A.Noon before 12:00 M steaming East, after 12:00 M when steaming West. Run the position at Departure or some line of position, which runs approximately North and South, up to this Watch T me and use the Longitude obtained as the approximate Longitude of L.A.Noon. When the watch is keeping L.A.T. at Noon to Noon each day, the watch error on L.A.Noon of the previous day is neglible for Practical Purposes, the hourly change in the Equation of Time being very small, we can use the values given in the Nautical Almanac for mean time intervals also, as if they were Apparent Time Intervals.

Between 8:00 a.m. and 10:00 a.m., it should be before the 10:00 a.m. observation, the watch is compared with the chronometer and set for Local Apparent Noon if keeping apparent time. By following the form we get the L.A.T. of comparison, remembering to subtract Longitude when West and add when East to G.A.T. of comparison to get L.A.Tc. The Watch Time of Comparison is then compared with L.A.Tc. and it is only necessary to set the watch so that L.A.T. = W.Tc. by their difference, if L.A.Tc. is greater we set the watch ahead, otherwise back.

After setting the watch it is again compared with the chronometer and error on G.M.T. obtained. Fill in under L.A.T. Noon in the form the best approximate Longitude you have for your new 12:00 M watch time and get the G.A.T. of Local Apparent Noon, apply the Eq. t., remembering to use opposite sign to that given in the N.A. and get the G.M.T. of Local Apparent Noon. The Watch Error is applied to the G.MT. giving the W.T. Local Apparent Noon.

In order to keep the minute and second hands of the watch together, the best practice is to set the watch to the nearest minute, less so that L.A.Noon occurs before watch time of Noon, rather than later, it is a matter of convenience except that the minute and second hand of the Navigating Watch must be kept together. After a little practice you will do most of this in your head, for instance if the change in Longitude is 12′ per hour, you know in 24 hours it is 288′ of arc or 288/15 = 19m of time, it is then apparent that the time will be changed about 19 m, so if steaming East the day will be 23 h and 41 m and if West 24 h 19 m. We figure our time intervals for running D.R. or Lines of Position to Noon and get the Longitude for Noon. This was not a matter of great importance in low speed vessels, but vessels are travelling the oceans making average speed of thirty knots and in twenty minutes they go ten miles, so that the speed of the vessel is becoming a much more important element in Practical Navigation.

EXAMPLE

At 8:00 p.m. 75th Meridian Mean Time, 8 May 1920, passed Chesapeake Bay Entrance Gas and Buoy, 2CB, close aboard, Lat. 36° 51.9′ N, Long. 75° 51′ W, Course 77° True, Speed 10 knots. R the amount and how to set the watch and clocks, the forenoon 9 May 1920, to have 12:00 M. t at L.A.Noon.

Since the watch is keeping 75th Meridian Mean Time it is 5 hours slow on G.M T.

W.T.	8-00-00 p.m.	8 May 1920.
W.Err.	5-00-00	
G.M.T	13-00-00	8 May As.M.T.
Eq. t	03-39.1	plus
G.A.T.	13-03-39.1	
Long.	5-03-24	75° 51′ converted into time.
L.A.T.	8-00-15.1	
W.T.	8-00-00	
W.Err.	0-00-15.1	slow on L.A.T. 8:00 p.m. 8 May 1920.

From Table 2 Bowditch speed 10 knots, Course 77° True, Dep. = 9.74 and for Lat. 37° Diff. L 12.2′ per hour of run.

From 8:00 p.m. to Noon is 16 hours, therefore 16 × 12.2 = 195.2′ of arc = 195.2 ÷ 15 = 13 m Since we are steaming to the Eastward we set the clocks back. The watch being 15.1 s slow on of the day before we estimate the amount to be set back as 13 m − 0 m 15.1 s = 12 m 44.9 Longitude is then figured to 12-00-00 − 0-12-44.9 = 11-47-15.1 a.m. The time interval fr p.m. night before is 15-47-15.1 = 15.79 hrs. so that the run will be 157.9 miles from 8:00 p.m.

		Lat. 36° 51.9′ N	Long. 75° 51′ W
157.9	77°	35.5′ N	3° 12.8′ E
		Lat. 37° 27.4′ N	Long. 72° 38.2′ W

From a comparison of the watch with the chronometer in the forenoon of 9 May 1920 we get as

C.Tc.	2–00–00	
c.c.	03–26	fast G.M.T.
G.M.Tc.	1–56–34	p.m. 9 May 1920
Eq. t.	03–40.8	plus
G.A.Tc	2–00–14.8	
Long.	4–50–32.8 W	72° 38.2′ converted into time.
L.A.Tc.	9–09–42	
W.Tc.	8–56–48	
	0–12–54	Set the watch ahead 13 m since L.A.Tc. is greater than W.T

Watch Time of L.A.Noon—L.A.T. Noon is 12-00-00 to which applying the Longitude, subt when East adding when West, gives the G.A.T. of LocalApparent Noon. Applying the Equ time, opposite in sign as given in the N.A. gives the G.M.T. of Local Apparent Noon, to which a the watch error, subtracting when slow, adding when fast, gives the Watch Time of Local Apparen

EXAMPLE

9 May 1920, Longitude L.A.Noon 72° 38.2′ W, W. Err. 4-46-46 slow G.M.T. Required the W.T. L.A. Noon.

L.A.T. Noon	12-00-00	
Long. L.A.Noon	4-50-32.8 W	
G.A.T. L.A.Noon	4-50-32.8 p.m. (9th)	
Eq.T.	−	-03-41.2 minus (plus in N.A.)
G.M.T. L.A.Noon	4-46-51.6 p.m. (9th)	
W. Err.	4-46-46 slow	
W.T. L.A.Noon	12-00-05.6 p.m.	

The value of the Equation of Time is practically the same for either a mean or apparent time interval, so we take the Eq. t. from the N.A. corresponding to 5 hours p.m. or 4.8 hours if you prefer to, there is no practical difference in the results. The sign in the Naut. Al. is for applying to mean time to get apparent time, therefore we apply in opposite way to convert apparent time into mean time.

Noon Konstant—Fill in after Lat. by D.R. the Latitude by D.R. or the best Latitude you have run to Noon. Fill in d the Declination of the Sun as obtained from the N.A. for either the G.A.T. or G.M.T. of Noon combining them to get the Zenith Distance z, the approximate altitude is 90°-z which in the form we call h by D.R. In the right hand center will be found a small circle, this is to be used if desired to determine how to combine L and d to get z, by marking in on the Meridian Circle the relative positions of the Sun and observer. For instance if d and L have the same name z is their difference, and if different name their sum.

The approximate altitude is desired in order to get the correction from Tab. 1. H.O. 200, which we fill in and combine with I. C. when given, to get Corr. the Total Correction.
This Corr. is added or subtracted from 90° in accordance with precepts given at the bottom of the form and the result combined with d to get the value of K called the Noon Konstant. It is thus called because it can be obtained in advance of the sextant observation, and when the sextant altitude is obtained we only have to combine K and hs by either one addition or subtraction and we have the Latitude. What ever extra labor there may be involved is justified and required because it saves time from the time the observation is taken to its solution and putting on the chart. Due to the Sun being reasonably high at Noon, the variation in Cor. Tab. 1 is very small for quite a change in Altitude near Noon, so that your Latitude by D.R. has to be rather wild to make any practical difference in the results.

Ex-Meridian or Near Noon Observations—As has been stated before for fractions of hours, a mean time interval and apparent time interval, so far as Practical Navigation is concerned may be considered equal. The form provides for taking observations beginning at 11-35-00 a.m. L.A.T. and filling in the corresponding Watch Times. The watch times are found by subtracting the number of minutes from Noon L.A.T. from the watch time of L.A.Noon, for instance 11-35 a.m. L.A.T. is 25 min. before Noon so we would subtract 25 m from W.T. L.A. Noon to get the corresponding W.T. of 11:35 a.m. L.A.T., 15 m to get W.T. of 11:45 a.m. L.A.T. etc.

From Table 26 Bowd. we find the change in altitude for 1 minute of time before Noon, depending on the Latitude of the Observer and the Declination of the body, which we call Δh in the form. The change for any other time interval from Noon is $\Delta h \times t^2$, t being the time interval in minutes and fraction thereof from Noon, the values of $\Delta h \times t^2$ being given in Table 27 Bowditch.

In using Table 26 Bowd. it should be noted, that it is only made out up to 60° Latitude, and that it is made up of Latitude and Declination of the same and opposite names. Referring to page 510 Bowd., the formulae are given from which Tables 26 and 27 are obtained. From Tab. 26 the intersection of the horizontal line from Latitude, in left and right hand vertical columns, with the number in the vertical column which has Declination of the body in degrees at the top, gives the value of Δh in seconds of arc.

Table 27 Bowd. gives the vertical columns in half minute time intervals from Noon and in the left hanc and right hand vertical columns Δh in seconds of arc from .1″ to 21″. Suppose Δh is 4.2″ and we wan the correction for 11:35 a.m. L.A.T. Since 11:35 a.m. is 25 m before Noon, we look in vertical columi for 25 m and find no value given for Δh = 4″, therefore the variation in altitude is too great, the rule t $\times \Delta h$ will not hold good, we find 4″ given first under 21 m; we cannot in this case begin our near Noo observations until 11:39 a.m. L.A.T., following our form, then we take the first observation at 11:45 a.m 15 m before Noon. The correction for 4″ is 15′ 00″ and for .1″ is 0′ 22″ so that for 4.1″ it will be 15 00″ plus 0′ 22″ = 15′ 22″ = 15.4′; that is at 11:45 a.m. our altitude would be 15.4′ less than at Noon provided our ship did not move in the meantime. We fill in under $t^2 \times \Delta h$ after 11:45 the value 15.4′ 11:55 the value 1.7′, 11:58 the value .3′ and after 12:00 the value 0.0′, on the assumption that Δh = 4.1″.

In the Lat. Speed column a correction is put for the change in Latitude due to the speed of the ship, i the interval from Noon. This is obtained from the True Course and speed of the vessel per hour, b the use of Table 2 Bowd. Let us assume Course 77° True, speed 10 knots bearing of the Sun South From Table 2 Bowd. the change in Latitude is 2.2′ per hour North, therefore since the Sun is South w are steaming away from the Sun, and the altitude at Noon will be less. At 11:45 a.m. which is ¼ hou from Noon ¼ × 2.2′ = .55′ or .6′, we accordingly enter in Lat. Speed column .6′ after 11:45 a.m., afte 11:55 a.m. 5/60 + 2.2′ = .2′, after 11:58 a.m. 2/60 x 2.2′ = .1′, and after 12:00 0. After determinin the sign of $t^2 \times \Delta h$, we write in the sign of Lat. Speed in accordance with the precepts given at the bottom o the form, combining $t^2 \times \Delta h$ and Lat. Speed in accordance with their signs getting a value which we ente in the total column, it taking the sign of the resulting combination. We combine this value with K o L.A.Noon and get a value entered under K varies as Total column. This value is obtained ahead o time so that when the sextant altitude is obtained, we merely combine it according with precepts give at the bottom of the form with the Konstant at time of observation, K varies as Total, and the Latitud is obtained by either addition or subtraction.

By working up the Noon Konstant as indicated in the form, we make ourselves independent of apparen dip, have the Noon Latitude before Noon so we can have the Longitude as well and the ship's positio when the bell strikes, thereby getting to lunch on time and cutting out the Noon farce of all hands stand ing around waiting for the Navigator to say "Twelve O'Clock." If the routine of your ship calls fo such procedure, when your watch shows the time you have figured for 12:00 M, yell "Twelve O'Clock' if you have to, for if you do not watch that watch, the first thing you know it will be ten minutes afte twelve, and you will still be waiting for the Sun to dip, and all hands will still be waiting to eat and hea you yell "Twelve O'Clock."

Longitude at L.A.Noon—After Position Point Diff. Obs. enter the Latitude and Longitude of point on the Line and after Factor F the value of Factor F for the Line of Position, and run the line t Noon by Table 2 Bowd. putting in after Dir. the direction of the Line. From a comparison of Lat Obs. and Lat.D.R. at Noon the drift in Latitude is obtained, which divided by the length of the day i hours gives the drift in Latitude per hour, multiplying the drift in Lat. per hour by the time interva from Line of Position Observation to Noon gives the "Drift in L time Diff. Obs. to Noon." It shoul be marked N or S according as the Lat. drift is North or South, and entered in the Form as indicate after "Drift in L Time Diff. Obs. to Noon." Under the Pos. Pt. to Noon Lat. after ΔL we put in a valu of ΔL so that combined with Pos. Pt. to Noon Lat., and Drift in L, they will equal the Lat. Obs. Noon Multiplying the ΔL by Factor F gives the amount to move the Long. Pos. Pt. to Noon, to get th Approximate Noon Longitude, which is uncorrected for Drift in Longitude from Time of Different Ob servation to Noon. The difference between this Longitude and the Longitude by D.R. at Noon is th Drift in Long. from Time of Departure to Time of Diff. Obs., dividing by the time interval in hours, give the drift in Longitude per hour, which multiplied by the time interval from Diff. Obs. to Noon, gives th correction to be applied to the Approximate Longitude to get the Longitude by Observation at L.A. Noon In connection with the method here given, I have obviated the necessity of moving anything back to time earlier than the present. The moving of a Line of Position back and crossing with a line take earlier, to obtain a ship's position, is like a Post Mortem, and is unsound Navigation Practice. Alway move Lines of Position from earlier observations to the latest observation, and then if you want to in vestigate, rectify lines of positions, or hold a Post Mortem, move the latest fix back. What is importan is "Where you are" and "Where you are heading" and not "Where you were " and "How you got there.'

In this form you have a Line of Position taken before Noon or after Noon, it being particularly for a forenoon Line of Position. The data up to Position Point to Noon and the Latitude and Longitude by D.R. is obtainable before Noon, depending on the speed and course of the ship. By the Ex-Meridian observation, the Latitude at Noon is obtainable within .2′ of accuracy and since Factor F will generally be less than one, our Longitude error will be less than .2′ of arc.

In moving the Latitude and Longitude of Position Point of the line to Noon we have erred by the amount of the drift. The amount of the Drift in Latitude is obtained from the Difference in the Lat. by D.R. and Lat. Obs. By combining in accordance with their letters so that Lat. plus ΔL plus Drift in Lat. = Lat. Obs., moving our Longitude of Position Point moved to NOON by an amount equal to $\Delta L \times$ Factor F, we get the Longitude for Noon uncorrected for drift in Longitude from the time of the Line of Position Observation to Noon. The difference between Long. by D.R. and this Longitude is the drift in Longitude from time of Departure to Time of the Line of Position Observation, because the Run by D.R. in Longitude from Time of the Line of Position to Noon is common and equal in both, therefore their difference is the same as the diff. in Long. by D.R. and Long. Obs. at the time of the Line of Position Observation. It is therefore only necessary to correct this approximate Noon Longitude by the drift in Longitude from time of the Line of Position Observation to Noon. The defect here is the assumption that the drift is constant, that is rate of drift between Departure and Time of Line of Position Observation, will be the same as the rate of drift from Time of Line of Position Observation to Noon. This is a rather uncertain assumption, but it is the best assumption to make. The Modern Skilled Practical Navigator using the Aquino or St. Hilaire methods no longer relies on a cross from a near Prime Vertical and Meridian Altitude sight, but obtains fixes from Lines of Positions whose angles are from 30° to 60°, obtaining Latitude and Longitude independent of Prime Vertical and Meridian Altitude Sights, the value of which observations are very much overrated. Until you have learnt to consider a Meridian sight as only a Line of Position running East and West True and a Prime Vertical sight a Line of Position running North and South True, and neither of any more value than any other reliable Astronomical Observation, save that of the Moon, you are still more or less a Novice in the game of Astronomical Navigation, and only entitled to be considered as an 8:00 o'Clock Navigator.

Course and Distance Made Good—By comparing Latitude and Longitude of Departure with Latitude and Longitude of Observation and obtaining the Course and Distance from Departure to Observation, we call this the Course and Distance Made Good. In the form it is done by use of Table 2 Bowd., and on the Middle Latitude Principle.

The Distance Made Good and Distance Steamed are frequently used synonomously, much to the detriment of our steaming data. When steaming in the open sea, on a steady compass course or approximately so as in Great Circle Changes, for Practical Purposes, Distance Steamed and Distance Made Good are the same. Under other conditions they are quite different and Distance Steamed is always greater than Distance Made Good.

EXAMPLE.

19 May, 1920, W.T. 7-14-40 a.m., obtained Line of Position Point Lat. 39° 18.7′ N, Long. 23° 00.5′ W, Direction of the line 19° True. L.A. Noon Lat. D.R. 39° 35.8′ N., Long D.R. 22° 02.5 W. A comparison with the chronometer is as follows: C.Tc. 9-10-00, c.c. 0-03-15 fast G.M.T., W.T.c. 7-22-09. Course S 85° E True, speed 10 knots. After setting the Watch to L.A. Noon its error on G.M.T. is 1-24-36 slow. Lat.Dep. 39° 51.3′ N., Long.Dep. 27° 06.5′ W. After setting the Watch to L.A. Noon obtained observations as follows: 11-44-52, hs 69° 51′ 10″; 11-54-52, hs 70° 05′ 20″; 11-57-52, hs 70° 06′ 50″; 11-59-52, hs 70° 07.′

Required the amount and how to set the watch to L.A. Noon, the Noon Konstant, Latitude and Longitude by observation at L.A. Noon, and the Course and Distance Made Good. Dip 27′. I. C. 0-00.

Applying the c.c. to C.T. of comparison gives G.M.Tc. 9-06-45 p.m. 19 May. From N.A. Eq. t. plus 3m 42s, so that G.A.Tc. is 9-10-27, reducing the Longitude D.R. Noon to time we get 1-28-10 W, applying it to G.A.Tc. subtracting as it is West, we get L.A.Tc. 7-42-17. The difference between L.A.Tc. and W.Tc. is 20 m 08 s and since L.A.Tc. is greater we set the Watch ahead 20 m.

The Long. by D.R. is 1-28-10 W, so the G.A.T. L.A.Noon is 1-28-10 p.m. to which applying the Eq. t. opposite in sign as given in N.A. we get G.M.T. L.A.Noon 1-24-28.4, applying W. Err. 1-24-36 to this subtracting as it is slow gives W.T. L.A.Noon 11-59-52.4.

Filling in L by D.R. and picking out d from N.A. corresponding to G.M.T. L.A.Noon and since they are the same name z = L − d = 19° 49.3′ and h by D. R. = 90° − 19° 49.3′ = 70° 10.7′. From Tab. 1 H. O. No. 200 Corr. is 10.4′, as the problem not stating the upper limb was observed, that the lower limb was observed is always taken for granted.

Since L and d are the same name and L greater d, K = 90° − Corr. plus d, we subtract the Corr. 10.4′ from 90° giving 89° 49.6′ and adding this to d 19° 46.5′ we get for K 109° 36.1′ and from the precepts L = K − hs.

From Table 26 Bowd. we get for Δh 4.2″ and it is important to get this value to the nearest tenth by interpolation when necessary. From Table 27 we see that we must wait until 21 minutes to twelve before taking the first observation and we could substitute in our form 11:39 for 11:35 if we desire, but in solving this problem we have started with 11:45 L.A.T. as the W.T. is 11-44-52 and the W.T. Noon 11-59-52.4, there being 15m difference. We thus get 15.8′ for 11-44-52, 1.8′ for 11-54-52, .1″ for 11-57-52, and 0.0 for 11-59-52. From Table 2 Bowd. Lat. Speed is .9′ S per hour and has the same sign as $t^2 \times \Delta h$ as we are steaming towards the Sun, or to be more correct as we steam along we get nearer the Sun. Combining $t^2 \times dh$ and Lat.Speed we get the Total and since hs is minus it will be minus and subtractive from K, therefore we get Konstants for 11-44-52, 109° 20.1′ and Latitude 39° 28.9′ and for the other times as set down in the appended form solution of the problem. The Noon Observation coming out 39° 29′ N.

Since the Watch has been set ahead twenty minutes since taking the a.m. observation, the interval to Noon will be 11-40-00 minus 7-14-40 = 4-25-20 = 4.42 hours and the run 10 x 4.42 = 44.2 miles and Course 95°. We accordingly move our Position Point 44.2 miles 95°, getting Lat. 39° 14.8′ N and Long. 22° 03.8′ W 1′ change of Lat. on Course 29° Table 2 Bowd. gives Dep. .556 miles which in Latitude 39° gives minutes change in Longitude .71, therefore Factor F = .71 E for change of 1′ N of Latitude on the Line.

The difference between Lat. D.R. 39° 35.8 and Lat.Obs. 39° 29′ is 6.8′ S which is the drift in Latitude for 23 h 40 m about 23.7 hours so the hourly drift is .29′ S and for 4.42 hours 1.3′ S. We now have to combine Lat 39° 14.8′ N, Drift 1.3′ S, and ΔL so they will equal Lat. 39° 29′ N. Lat 39° 14.8′ N plus 1.3′ S = 39° 13.5′ N plus ΔL = 39° 29′ N therefore ΔL = 15.5′ N. Multiplying ΔL by Factor F = 15.5′ N × .71 = 11′ and since the Line runs 29° if we move to the North on the line we must move to the East so we mark it E. Applying this to Longitude of Line moved to Noon we get the Approximate Noon Longitude 21° 52.8′ W. Comparing with 22° 02.5′ D.R. Longitude gives Drift in Longitude 9.7′ East which is for period 12 plus 7-14-40 or 19 h 14 m 40 s or 19.25 hours, giving hourly drift in Longitude .50′. The drift for 4.42 hours is 2.2′ Long. We apply this to 21° 52.8′ and to the Eastward getting Longitude by observation L.A. Noon 21° 50.6′ E.

The ordinary practice is to subtract 39° 14.8′ from 39° 29′ giving 14.2′ N and multiplying by F .71 = 10.1′ Longitude E, this would be applied to 22° 03.8′ W giving the Noon Longitude 21° 53.7′ W making an error of 3.1′ of Longitude in the Noon Position, the principal reason for this discrepancy as we will find out from our Course and Distance Made Good is that we have made more than 10 knots speed. By taking into consideration the drift we pick this error up.

We now find the Course and Distance from Departure to Observation by Table 2 and Middle Latitude Method. The Middle Latitude is 39° 40′ so we use 40° and Diff.Long. is 315.9′ and p = 242′. We get Course Angle 85° and since S and E pick out 95° and the Distance is 242 .9′. Dividing 242.9 miles by the time interval 23.7 hours gives speed 10.25 knots.

It is because of the many small errors in assumptions, taking of Altitudes, marking of time, comparisons of the watch, chronometer rates, etc., that may be accumulative, creeping into the Practical Navigator's work, that we have stated elsewhere in this book that good Astronomical Fixes at sea should be assumed to be in error as much as three miles, we desire to emphasize here again that statement.

McCRACKEN FORM 6

SUN—NOON—D. R.

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Civil Date

L.A.T. Noon 12 h 00 m 00.0 s
λong.L.A.Noon 1 h 28 m 10.0 s

G.A.T.L.A. Noon 1 h 28 m 10.0 s p.m.
Eqt.L.A. Noon h 3 m 41.6 s

G.M.T.L.A. " 1 h 24 m 28.4 s
W.Err.G.A.T. 1 h 24 m 36.0 s slow

W.T.L.A. Noon 11 h 59 m 52.4 s

L.D.R. 39° 35.8′ N
d 19° 46.5′ N

Z 19° 49.3′
h D.R. 70° 10.7′

I. C.
H.O. 200 Cor. Table 1 10.4′ (Tab. 46 Bowditch)

90° ∓ Corr. 10.4′ = 89° 49.6′

L = Z ∽ d = 90° − (hs + Corr.) ∽ d = 90° − Corr. ∽ d − hs = K − hs
K = 90° − Corr. ∽ d = 109° 36.1′

Δh = 4.2″ Tab. 26 Bowditch

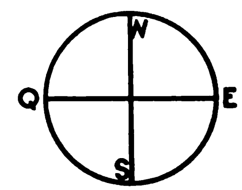
C.Tc. 9 h 10 m 00.0 s
C.C. − h 3 m 15.0 s

G.M.Tc. 9 h 06 m 45.0 s
Eq. t + 0 h 3 m 42.0 s

G.A.Tc. 9 h 10 m 27.0 s
Approx. λ Noon 1 h 28 m 10.0 s

L.A.To. 7 h 42 m 17.0 s
W.Tc. 7 h 22 m 09.0 s
Set Watch AHEAD BACK h 20 m 08.0 s

	Tab. 27 Bowditch	t² × Δh	Lat. Speed	Total	K ∽ Total ∽ h s	
				′	° ′ ∽ ° ′ = ° ′	L Noon
W.T. 11 h 34 m 52.4 s	L.A.T. 11-35-00	28.0′	+.3′			L Noon
W.T. 11 h 44 m 52.4 s	L.A.T. 11-45-00	15.8′	+.2′	16.0′	109° 20.1′ ∽ 69° 51.2′ = 39° 28.9′	L Noon
W.T. 11 h 54 m 52.4 s	L.A.T. 11-55-00	1.8′	+.1′	1.9′	109° 34.2′ ∽ 70° 05.3′ = 39° 28.9′	L Noon
W.T. 11 h 57 m 52.4 s	L.A.T. 11-58-00	.1′	− ′	.1′	109° 36.0′ ∽ 70° 06.8′ = 39° 29.2′	L Noon
W.T. 11 h 59 m 52.4 s	L.A.T. 12-00-00	− ′	− ′	− ′	109° 36.1′ ∽ 70° 07.0′ = 39° 29.1′	L Noon



Pos. Pt. Diff. Obs. Lat. 39° 18.7′ N λong. 23° 00.5′ W Factor F .71′ Noon L Obs. 39° 29.0′ N λObs. 21° 50.6′ W
C 95° Dist. 442′ ΔL. ° 3.9′ S Δλ ° 56.7′ E L Dep. 39° 51.3′ N λDep. 27° 16.5′ W

Pos. Pt. to Noon Lat. 39° 14.8′ N λong. 22° 03.8′ W Dir. 29° ΔL. ° 22.3′ S Δλ 5° 15.9′
ΔL. ° 15.5′ N Δλ ° 11.0′ = F × ΔL ΔL. 22.3′ S Δλ 315.9′ E

Drift in L Time Diff. Obs. to Noon ° 1.3′ S λong. 21° 52.8′ W λong. 21° 52.8′ W p 242.0′ E

LNoon 39° 29.0′ N λD.R. 22° 02.5′ Drift ° 2.2′ E C 95°

Drift in λong. Time Dep. to Time Diff. Obs. 9.7′ E λObs. 21° 50.6′ E Noon Dist. made good 242.9′

L and d same name L > d	L = 90° − Corr. + d − hs	K = 90° − Corr. + d
L and d same name d > L	L = hs − (90° − Corr. − d)	K = − (90° − Corr. − d)
L and d opp. name	L = 90° − Corr. − d − hs	K = 90° − Corr. − d
L and d same name Lower Transit	L = 90° + Corr. − d + hs	K = 90° + Corr. − d

McCRACKEN FORM 6

SUN—NOON—D. R.

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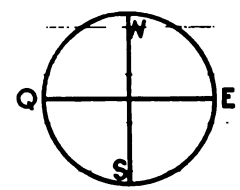
Civil Date

L.A.T. Noon	12 h 00 m 00.0 s	L.D.R.	° ′	I. C.		C.Tc.	h m s
λong.L.A.Noon	h m s	d	° ′	H.O. 200 Cor. Table 1	′ (Tab. 46 Bowditch)	C.C.	h m s
G.A.T.L.A. Noon	h m s	Z	° ′	90° ∓ Corr.	′ = ° ′	G.M.Tc.	h m s
Eq. t L.A. Noon	m s	h D.R.	° ′			Eq. t	0 h m s
G.M.T.L.A. "	h m s	L = Z⌣d = 90° − (hs + Corr.)⌣d = 90° − Corr.⌣d − hs = K − hs				G.A.Tc.	h m s
W.Err.G.M.T.	h m s	K = 90° − Corr. ⌣ d =	° ′		Approx.	λ Noon	h m s
W.T.L.A. Noon	h m s	Δh =	″ Tab. 26 Bowditch			L.A.To.	h m s
						W.Tc.	h m s
					Set Watch	AHEAD BACK	h m s

	Tab. 27 Bowditch	$t^2 \times \Delta h$	Lat. Speed	Total	K ⌣ Total	⌣ h s		
W.T. h m s	L.A.T. 11-35-00	′	′	′	° ′ ⌣	° ′ =	° ′	L Noon
W.T. h m s	L.A.T. 11-45-00	′	′	′	° ′ ⌣	° ′ =	° ′	L Noon
W.T. h m s	L.A.T. 11-55-00	′	′	′	° ′ ⌣	° ′ =	° ′	L Noon
W.T. h m s	L.A.T. 11-58-00	′	′	′	° ′ ⌣	° ′ =	° ′	L Noon
W.T. h m s	L.A.T. 12-00-00	′	′	′	° ′ ⌣	° ′ =	° ′	L Noon



Pos. Pt. Diff. Obs.	LAT. ° ′	λong. ° ′	Factor F ′	Noon L Obs.	° ′	λObs.	° ′
C ° Dist. ′	ΔL. ° ′	Δλ ° ′		L Dep.	° ′	λDep.	° ′
Pos. Pt. to Noon	LAT. ° ′	λong. ° ′		ΔL.	° ′	Δλ	° ′
	ΔL. ° ′	Δλ ° ′	= F×ΔL	ΔL.	′	Δλ	′
Drift in L Time Diff. Obs. to Noon	° ′	λong. ° ′	λong. ° ′			p	′
	L Noon ° ′	λD.R. ° ′	Drift ° ′			C	°
Drift in λong. Time Dep. to Time Diff. Obs.		′	λObs. ° ′	Noon		Dist. made good	′

L and d same name L > d	L = 90° − Corr. + d − hs	K = 90° − Corr. + d	$t^2 \times \Delta h$ has same sign as h s
L and d same name d > L	L = hs − (90° − Corr. − d)	K = − (90° − Corr. − d)	Lat. Speed has same sign as h s when
L and d opp. name	L = 90° − Corr. − d − hs	K = 90° − Corr. − d	steering towards the Sun, and
L and d same name Lower Transit	L = 90° + Corr. − d + hs	K = 90° + Corr. − d	Opp. sign steering away from Sun.

THESE FORMS CAN BE PURCHASED (IN PADS OF 25) FROM YOUR DEALER OR BY MAIL FROM J. J. MC CRACKEN, NORFOLK, VA.

McCRACKEN FORM 7

NOON DATA

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Civil Date

Miles steamed	238	log		2.37658
Coal expended, tons		log	−	2.07918
Miles steamed, per ton coal		log		.29740
Coal on hand, tons	1100	log		3.04139
Steaming radius, miles	2182.7	log		3.33879
Miles to Port	1987.0	log		3.29820
Ziege Factor	1.098	log		.04059
6080.27		colog		6.21607–10
Pitch Propeller in feet	17′	log		1.23045
Total Revolutions	106585			5.02770
Miles steamed by screw	298	log	−	2.47422
Miles steamed	238			
Difference	60	log	+	1.77815
Slip 20.1%	.20131	log		9.30393–10

SHIP'S POSITION

At

S. S.

Lat. by Observation		°		′
Long by Observation.		°		′
Lat. by D.R.		°		′
Long. by D.R.		°		′
Set °		Drift		m.p.h.
Av. Dir. Wind °	True		Force	
Coal Ex. Tons	Coal Rem.			Tons
Length Day h	m			
Distance steamed since				miles
Distance to				miles
Steam Radius	miles		Ziege F.	
Error Std. Comp. S. H.	°		°	′
Var. by			°	′
Rev. Std. Comp. S. H.	°		°	′

Remarks:

CHAPTER 8

McCracken Form 8

Stars—Planets—Moon.
Merchant Marine Practice.
Sumner Line—Time Sight—Meridian.

Greenwich Mean Time—In finding the G.M.T. we have conformed to the C-W method, that is subtracting the W.T. of Comparison from the G.M.T. of Comparison to get C-W. The watch time of observation, W.To. is added to the C-W giving the chronometer time of observation, C.To., to which the chronometer correction, c.c., on G.M.T. is applied giving the G.M.T. of observation. When the chronometer is slow on G.M.T., c.c. is plus or additive, when fast minus or subtractive.
In using the form where a Longitude and Latitude observation have both been taken, find the G.M.T. of the Longitude observation first. Since the time interval between the observations should be less than half hour, except in the case of the Moon, we can pick the Right Ascension and Declination out for both bodies from the Nautical Almanac for the G.M.T. of the Longitude Observation.

Greenwich Sidereal Time—From page 2 and 3 of the Nautical Almanac pick out the Right Ascension of the Mean Sun, and Correction for the G.M.As.T., interval from Greenwich Mean Noon. Remember that when G.M.T. is a.m. you add twelve hours and use the civil date of the previous day. Adding R.A.M.⊙., Cor., and G.M.As.T. we get the G.S.T., should the sum be greater than 24 hours, subtract 24 hours from the hours before writing it down.

Declination and Right Ascension—Fill in Left Hand Column, the Declination of the Longitude Body and on the thirteenth line from the top in the form its Right Ascension, R.A.*. After Mer.* d, fill in the Declination of the Meridian Body, and after R.A.* right hand column, fifteenth line, its Right Ascension. From the difference in W.T. of the two bodies and the hourly change in d and R.A. of the Latitude Body, it will be seen whether it will be sufficient to use the G.M.T of the Longitude body except in the case of the Moon, it rarely makes any practical difference. The Declination of the Longitude body is reduced to Polar Distance, P.D., from the elevated pole, that is d and L same name P.D. = 90° − h, different name P.D. = 90° plus d.

Corrected Altitudes—The Index Correction, I.C., when given, is entered and the sextant altitudes, hs, are entered as indicated, and from Table 46 Bowd., in case of Stars and Planets, Table 49 Bowd.,in case of the Moon, the Correction is obtained, which combined with I.C. gives Corr. which applied to hs gives the altitudes of observation ho. In using Table 49 for the Moon do not forget it is figured for dip of 35′ therefore you have a correction to make at the bottom of page in the Bowditch. Some Navigators would proceed next with the solution of the Meridian Star by using the Longitude by D.R., and the form permits that contingency, and then use his Latitude obtained as the assumed Latitude in the Time-Sight calling the result the Longitude by observation. We do not approve of the practice for the Assumed Longitude may be in error, therefore t, and since you multiply Δh by t^2 to get the correction for Mer.* ho to get hm, at over 10 minutes from transit as we are increasing the error in proportion to the square of t, the error is becoming appreciable. It is our practice therefore to solve the Time-Sight or Sumner Line first.

Sumner Line—The formula for the solution of the Time-Sight or Longitude by Chronometer is $2 \sin^2 \frac{1}{2} t$ = cosec Polar Distance times Sec. Latitude times cosines times sin s-h where 2 S = P.D. plus L plus h.

In the Sumner Line we assume two Latitudes and get the two corresponding Longitudes, between the points obtained a line is drawn extending on both ends, called the Sumner Line or Line of Position. The number of minutes difference in Latitude assumed, less than sixty, is not usually a matter of importance so far as practical results go. In our practice we have assumed 20 minutes difference, the purpose being to work both solutions together, to keep the minutes and seconds for the same functions the same, to save time and labor in the work.

When the observed body is near the Prime Vertical, that is bears near East or West True, the Line of Position runs nearly North and South True, so that a change or error in Latitude makes only a small change in Longitude, and the Longitude obtained for a single solution is almost practically the Longitude of Observation. It has been commonly accepted as True, that a solution of the Astronomical Triangle by the Time-Sight formula, is limited to observations near the Prime Vertical, such is not quite the case however, as you can demonstrate by working observations not nearer than two hours of Meridian, by Aquino, St. Hilaire, and Time Sight formulae and see if you do not get practically the same line of position. What is correct is that as the body moves from the Prime Vertical towards the Meridian, the change in Longitude on the Line of Position corresponding to 1′ change in Latitude increases, and finally becomes so great, that the line may not be located or drawn in by connecting the two points, without appreciable error, due to the fact that the chord and the arc of the altitude circle do not coincide within practical limits on account of their length. It may therefore be adopted as good practice, that when the body is closer to the Meridian than 45° of azimuth, the Time Sight formula does not offer a Practical Navigation Solution of the Astronomical Triangle.

Local Hour Angle—Fill in Polar Distance of the Body and Latitude about ten minutes less than Latitude by D.R. to the nearest minute. It really is not so important that it be any closer than thirty minutes of the D.R. position so long as it is less. Add ho, P.D., and Lat. getting 2 S, dividing by 2 getting S, subtracting ho from s getting s-ho.

Find Log cosec P.D. and put it in both solution columns. Pick out log sec Lat and after 20′ put in log sec of an angle 20′ greater. After cos s put in log cos s and after 10′ log cos of angle 10′ greater. After sin s-ho put in log sin s-ho and after 10′ log sin of angle 10′ greater. Add up both logarithm columns and divide by 2 giving log sin ½ t. We find the two t's writing them in under R.A.*, marking them minus if the body is East and plus if West. R.A. plus H.A. or t = L.S.T., so we get the L.S.T. for Latitudes 20′ apart. The difference between the G.S.T. and L.S.T. is the Longitude. Factor F = Diff. in Longitudes divided by twenty. By finding the course as in Middle Latitude sailing between the two points we get the direction of the Line True. The Azimuth or Bearing of the body is 90° from the direction of the line.

Hour Angle of Meridian Body—The L.S.T. of the Longitude Star is corrected for the difference between the watch times of the Longitude Body and Meridian Body in the right hand column and the L.S.T. for the Meridian Body obtained. By combining R.A. Meridian Body with L.S.T. we get t or its Hour Angle. It is seldom necessary to correct Δ.W.T. for its interval to reduce to a sidereal interval as the correction is only 1s for each six minute mean time interval. In order to follow the rule $t^2 \times \Delta h$ the value must be less than 26 m.

$t^2 \times \Delta h$—From Table 26 Bowditch and Latitude and Declination as arguments we get Δh. By using Table 27 Bowditch we get the value $t^2 \times \Delta h$ which applying to the ho gives hm, the altitude reduced to Meridian transit at the place of observation. Subtracting hm from 90° gives the Zenith distance of the body.

Latitude by Meridian Body—Combining d and z in accordance with precepts at the bottom of the form gives the Lat. by the Meridian body. If the body is actually observed on the Meridian then $t^2 \times \Delta h = 0$. Due to the presence of clouds and the getting of a good horizon at twilight an actual Meridian Transit observation of a Star or Planet is more or less accidental, therefore unsound Navigation practice to rely on. Take the large stars and planets as you find them as near Sunrise and Sunset as you can get them 30° to 60° apart in azimuth. Do not waste valuable time trying to watch for a Star, Planet, or Moon to dip at Sunrise or Sunset.

EXAMPLE

13 June 1920, p.m., W.To. 7-48-02, sextant h of Jupiter 34° 57′ bearing West; W.To. 7-51-12, sextant h of Spica 43° 23′ bearing South; height of eye 43 feet. Compared the watch with the Chronometer C.T. 10-04-30, W.Tc. 7-54-23, c.c. 3 m 22.8 s fast on G.M.T. D.R. Position Lat. 36° 00′ N, Long. 34° 00′ W. Required the Sumner Line of Position and the Latitude of Observation.

Following the Form, subtracting W.T.c from C.Tc. we get C-W = 2-10-07, C.To. 9-58-09, and G.M.T. 9-54-46.2 = 9.91 hours = 9.91/24 = .41 days, since the Longitude is West and Civil Time p.m., the Greenwich Mean Astronomical Time is .41 days after Greenwich Mean Noon 13 June 1920.

From the Nautical Almanac:

JUPITER

13 June 1920	d	17° 10.9′	N	3.0	R.A.	9-10-08	41
		−° 01.2′		.41	+	-16.8	.41
	d	17° 09.7′	N	1.23	R.A.	9-10-24.8	41
	d	17° 09′ 42″	N				16 4
							16.81

SPICA

June 1920 d 10° 44.9′ S R.A. 13-21 01.5

The Longitude by D.R. is 34° 00′ = 2 h 16 m W.

	Jupiter		Spica
G.S.T.	15-22-22.4		13-06-22.4
Long.	2-16-00 W	Δ.W.T.	03-10
L.S.T.	13-06-22.4	L.S.T.	13-09-32.4
R.A.	9-10-24.8	R.A.	13-21-01.5
t	3-55-57.6 West	–	-11-29.1 East

Since the H.A. of Jupiter is nearly 4 hours and Spica about 11 m, we use Jupiter for the Sumner Line and Spica for reduction to the Meridian, solving for the Sumner Line first.

Following our practice we assume Latitudes 35° 50′ N and 36° 10′ N, since the Latitude by D.R. is 36° 00′ N. Filling in the left hand column with Lat. 35° 50′, we get s 71° 44′ 45″ and s-ho 36° 55′ 34″. The column with Lat. 36° 10′ may be filled in also if desired. In order to obviate this we have placed the plus 20′ and plus 10′ opposite the log functions of the left hand column, picking out from the Tables the same log functions for the two solutions in succession, while we have the page open in the Bowditch Table 44, saving time in turning the pages of the Tables and finding practically the function of the same angle twice.

We pick out, Table 44 Bowd., log cosec P.D. writing the value in both solution columns; log sec Lat. writing it in the first solution column and log sec of an angle 20′ greater in value having the same minutes and seconds entering it in the second solution column; log cos s in first solution column and for angle 10′ greater in second solution column; and log sin s-ho in first solution column and for angle 10′ greater in the second solution column. Adding up the vertical solution columns we get log $\sin^2 \frac{1}{2}$ t or log Haversine t. Some Navigators prefer to eliminate dividing by two and interpolating by Table 45 Bowd., so they pick the value of t from its log Haversine from Table 45 Bowd., working only to the nearest second of time. Our form covers both ways of doing it, you can take your choice, they both give the same results within a few tenths of seconds. We get for one t 3-56-17.7 and the other t 3-56-08.3, which applying to the R.A., adding as the bearing of Jupiter is West, we get L.S.T. 13-06-42.5 and L.S.T. 13-06-33.1. The difference between G.S.T. and L.S.T. gives Longitude, therefore the Longitudes become 2-15-39.9 = 33° 55′ and 2-15-49-3 = 33° 57.3′ West, their difference is 2.3′ so that Factor F = 2.3/20 = .12′. From Table 2 Bowd. p = 1.86 miles and p/20 = tan Direction of the Line of Position. The Direction of the Line is N 5° 19′ W or S 5° 19′ E and the Z or bearing 360° − 5° 19′ − 90° = 264° 41′, in order to get the Compass Error, in case a compass bearing was taken, logarithms have been used rather than Table 2 Bowditch.

The mean of the two L.S.T.'s is 13-06-38.2 and the Δ.W.T. is plus 3 m 10 s, since Spica was observed later than Jupiter, giving Spica L.S.T. 13-09-48.2 and t 11 m 13.3 s. Table 26 Bowd. Δh = 2.1″ and as Table 27 Bowd. only gives values for $t^2 \times \Delta h$ for even half minute intervals, the nearest to 11 m 13.3 s is 11 m. Some Navigators would interpolate for the 13.3 s and some would consider the time interval 11 m, but as the value varies as the square of the time interval, neither practice is mathematically correct,

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d	17° 09′	42.0″ N	
P.D.	72° 50′	18.0″	
I.C.	0° ′	″	
Cor. Table 46	0° 7′	49″	
Corr. −	0° 07′	49″	
hs+	34° 57′	″ Long*	
ho +	34° 49′	11″	
P.D. +	72° 50′	18″	
Lat. +	35° 50′	00″ N	
	2s)143° 29′	29″	
S	71° 44′	45″	
s−ho	36° 55′	34″	
R.A.*+	9h 10m 24.8s		
t*+	3h 56m 17.7s		
L.S.T.	13h 06m 42.5s	>G.S.T. Long. East	<G.S.T. Long.West
G.S.T.	15h 22m 22.4s		
λong.	2h 15m 39.9s		
λong.	33° 55.0′	″ W	
λong.	33° 57.3′	″ W	
Δλ	2.3′	p = W	

I.C.	0° ′ ″		
Cor. Table 46	0° 08.6′ ″		
Corr. −	0° 08.6′ ″		
Mer.* hs +	43° 23.0′ ″		
ho +	43° 14.4′ ″		
t²×Δh +	° 04.4′ ″		
hm	43° 18.8′ ″		
Cosec	.01977		.01977
Sec.	.09133	+20′	.09296
Cos.	9.49587	+10′	9.49203
Sin	9.77872	+10′	9.78039
	2)9.38569		2)9.38515
Sin	9.69284		Sin 9.69257
Lat.	35° 50.0′	″ N	
Lat.	36° 10.0′	″ N	
			p=1.86′
ΔL.	20.0′N		

Mer. * d	10° 44.9′	S
Mer. * z	46° 41.2′	
Lat.	35° 56.3′	N
Long.*W.To.+	7 h 51 m 12 s	
Mer.* W.T. −	7 h 48 m 02 s	
ΔW.T. +	h 3 m 10 s	
ho	34 ° 49 ′ 11 ″	
P.D.	72 ° 50 ′ 18 ″	
Lat.	36 ° 10 ′ 00 ″	
	2s)143 ° 49 ′ 29 ″	
S	71 ° 54 ′ 45 ″	
S−ho	37 ° 05 ′ 34 ″	
R.A.*+	9 h 10 m 24.8 s	
t±	3 h 56 m 08.3 s	
L.S.T.	13 h 06 m 33.1 s	
G.S.T.	15 h 22 m 22.4 s	
λong.	2 h 15 m 49.3 s	
λong.	33 ° 57.3′ W ″	
log +	.26951	
log −	1.30103	

C.Tc.	10 h 04 m 30 s	
W.Tc.	7 h 54 m 23 s	
C.−W.	2 h 10 m 07 s	
W.To.	7 h 48 m 02 s	
C.To.	9 h 58 m 09 s	
C.C.−	h 3 m 22.8 s	
G.M.T. +	9 h 54 m 46.2 s	
R.A.M.⊙+	5 h 25 m 58.6 s	
Cor.+	h 1 m 37.6 s	
G.S.T.+	15 h 22 m 22.4 s	
λD.R.±	h m s	
L.S.T.+	13 h 06 m 38.2 s	
ΔW.T.±	h 3 m 10.0 s	
L.S.T.+	13 h 09 m 48.2 s	
R.A.*−	13 h 21 m 01.5 s	
*t± −	0 h 11 m 13.3 s	
Δh	2.1″	Tab. 26 Bowd.
t²×Δh	4.2′	Tab. 27 Bowd.

*t less than 26 m Meridian *

Zc = 90° ± Dir. Line = 264° 41′ Dir. Line N 15° 19′ W tan 8.96848–10 Factor F .12′

L and D same name	L > d	L = z + d	
L and d same name	d > L	L = d − z	λong. = ∓ G.S.T. ± L.S.T., L.S.T. > G.S.T. λong. E. < λong. W.
L and d Opp. name		L = z − d	L.S.T. = R.A. * + t
L and d same name Lower Transit		L = 180° − (z + d)	When Body is East t is Minus; West t is Plus.

McCRACKEN FORM 8

STAR SIGHT (MERIDIAN AND TIME SIGHT)

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Civil Date

d	°	′	″	I.C.	0°	′	″	Mer. * d	°	′		C.Tc.	h	m	s
P.D.	°	′	″	Cor. Table 46	0°	′	″	Mer. * z	°	′		W.Tc.	h	m	s
I.C.	0°	′	″	Corr. −	0°	′	″	LAT.	°	′		C.−W.	h	m	s
Cor. Table 46	0°	′	″	Mer.* hs +	°	′	″	Long.*W.To.+	h	m	s	W.To.	h	m	s
Corr. −	0°	′	″	ho +	°	′	″	Mer.* W.T.−	h	m	s	C.To.	h	m	s
hs+	°	′	″	Long* t²×Δh +	°	′	″	ΔW.T.	h	m	s	C.C.−	h	m	s
ho +	°	′	″	hm	°	′	″	ho	°	′	″	G.M.T. +	h	m	s
P.D. +	°	′	″	Cosec				P.D.	°	′	″	R.A.M.⊙+	h	m	s
LAT. +	°	′	″	Sec.	+20′			LAT.	°	′	″	Cor.+	h	m	s
2s)	°	′	″					2s)	°	′	″	G.S.T.+	h	m	s
S	°	′	″	Cos.	+10′			S	°	′	″	λD.R.±	h	m	s
s−ho	°	′	″	Sin	+10′			S−ho	°	′	″	L.S.T.+	h	m	s
R.A.*+	h	m	s	2)	2)			R.A.*+	h	m	s	ΔW.T.±	h	m	s
t*±	h	m	s	Sin	Sin			t±	h	m	s	L.S.T.+	h	m	s
L.S.T.	h	m	s	>G.S.T. Long. East	<G.S.T. Long. West			L.S.T.	h	m	s	R.A.*−	h	m	s
G.S.T.	h	m	s					G.S.T.	h	m	s	*t± −	0h	m	s
λong.	h	m	s					λong.	h	m	s	Δh	″ Tab. 26 Bowd.		
λong.	°	′	″	Lat.	°	′	″	λong.	°	′	″	t²×Δh	′ Tab. 27 Bowd.		
λong.	°	′	″	Lat.	°	′	″ p = ′	log +				*t less than 26 m			
Δλ		′ p =	′	ΔL.	20′			log −	1.30103			Meridian *			
Zc = 90° ± Dir. Line =	°	′		Dir. Line	°	′		tan				Factor F	′		

L and D same name L > d L = z + d

L and d same name d > L L = d − z λong. = ∓ G.S.T. ± L.S.T., L.S.T. > G.S.T. λong. E. < λong. W.

L and d Opp. name L = z − d L.S.T. = R.A. * + t

L and d same name Lower Transit L = 180° − (z + d) When Body is East t is Minus; West t is Plus.

THESE FORMS CAN BE PURCHASED (IN PADS OF 25) FROM YOUR DEALER OR BY MAIL FROM J. J. McCRACKEN, NORFOLK, VA.

but interpolation gives closer results. My practice is to interpolate as follows: 13.3/30 = .4; 4′ 24″ − 4′ 02″ = 20″; 20″ × .4 = 8″; 4′ 02″ plus 08″ = 4′ 10″; for .1 t we get 0′ 12″; therefore I would use as $t^2 \times \Delta h$ 4′ 20″ plus 0′ 12″ = 4′ 22″ = 4.4′. Adding 4.4′ to ho = hm 43° 18.8′ and z = 90° − hm = 46° 41.2′, and since L and d are opposite name L = z − d = 35° 56.3′ N. The precepts given at the bottom of the form will be found very handy and useful.

PRACTICAL EXAMPLES

(62) At W.To. 7-13-22 p.m., 11 May 1920, hs Arcturus 39° 16′, Compass bearing 115° p.s.c., approximate position Lat. 38° 30′ N, Long. 61° 30′ W, Dip 39 feet. C.Tc. 11-25-00, W.Tc. 7-18-20, c.c. 1 m 30 s slow on G.M.T. at W.To. 7-14-20, hs Saturn 63° 10′ bearing South. Required the Ship's position at 8:00 p.m.

(63) 14 June 1920 p.m., approximate position Lat. 36° 00′ N, Long. 38° 30′ W, dip 39′, W.Err. 2-30-06 slow G.M.T., obtained following observations: Mars W.T. 7-43-37, hs 44° 40.5′; Jupiter W.T. 7-45-50, hs 33° 46.5′. Required the Ship's position at 8:00 p.m.

CHAPTER 9

McCracken Form 9

Sun.
Merchant Marine Practice.
Time Sight or Longitude by Chronometer — Sumner Line.
Time Azimuth — Compass Error and Deviation.

McCracken Form 9—This Form is very similar to McCracken Form 8. It differs from it in Greenwich Apparent Time is obtained instead of Greenwich Sidereal Time, and that there is an addition to the Form, for finding the azimuth from the Time-Azimuth Tables.

G.M.To.—G.A.To.—Sun's Declination—Just before or after taking the observation, the watch is compared with the chronometer, and the chronometer minus the watch time, C-W, is obtained. The watch time of observation is added to the C-W, giving the chronometer time of observation, C.To., to which the chronometer correction, c.c., is applied adding when slow, subtracting when fast, on G.M.T., giving the Greenwich Mean Time of the observation, G.M.To. The Declination and Equation of Time are obtained from the Nautical Almanac, pages 6-29, for the Greenwich Mean Astronomical Time, that is if G.M.To. is p.m. we use the Civil Date, and G.M.To. as the interval from Greenwich Mean Noon, if G.M.To. is a.m. we use the Civil Date of the previous day and add 12 hours to the G.M.To. to get the mean time interval from G.M. Noon of the previous day. The Equation of Time is applied to G.M.To., in accordance with the sign given in front of it in the Nautical Almanac, to get the Greenwich Apparent Time of the observation, G.A.To.

When Latitude and Declination are the same name, Polar Distance, P.D., is 90° minus d, and if opposite in name P.D. is 90° plus d.

The difference between G.A.To. and the computed L.A.To. gives the Longitude.

Altitude, L.A.To, and Longitude—The sextant altitude, hs, is corrected for index correction, I.C. if any and for the dip, refraction, parallax, and semi-diameter of the Sun's Lower Limb by use of Table 46 Bowditch. At the bottom of the Table is a small additional correction for variation of the Sun's semi-diameter at different times of the year. If in cloudy weather you take the Top Limb, that is when the Top of the Sun is tangent to the horizon, subtract twice the semi-diameter given in the Nautical Almanac, from the correction as obtained from use of Table 46, which gives a negative value which subtracting from hs corrected for I.C. gives the observed Altitude ho.

Assuming a Latitude, to even minutes, about ten minutes less than the D.R. or approximate Latitude, and adding ho, P.D., and Lat., we get 2s, dividing by 2 we get s, and subtracting ho from s gives s − ho. From Table 44 Bowditch, we find log cosec P.D. putting it in both vertical solution columns; log sec Lat. putting it in left vertical solution column, and log sec of an angle 20′ greater putting it in the right solution column; log cos s putting it in the left vertical solution column and for Log cos angle 10′ greater putting it in the right vertical solution column; and log sin s-ho putting it in the left vertical solution column and log sin of an angle 10′ greater putting it in the right vertical solution column.

We have assumed Latitudes 20′ apart in order to avoid the necessity of filling in the right hand vertical angle column, by keeping the seconds the same in both vertical columns. You may fill in the right hand vertical angle column if you desire and assume any difference in Latitudes from 15′-30′, modifying the right hand solution column accordingly. It will be well to do this at first in order to verify the mental arithmetic involved in adding 20′ and 10′ when the Latitudes are assumed 20′ apart. What we are accomplishing is the picking out of the same function for the two solutions, while the page of the table is open, obviating the turning of additional pages, to find the functions for the second solution. After you have become accustomed to the method, you will find a further saving in time, by picking out the functions log cosec P.D., log cos s, log sin s-ho, and log sec Lat in the order given. This further saving

of time and labor, is due to the fact, that in using the Time-Sight formula the Hour Angle is generally greater than three hours, so that P.D. and s are near each other and s-ho and Lat are near together in the Tables, so that a saving in turning pages of the tables is accomplished by picking out the functions in the order stated.

Summing up the vertical solution columns we get log $\sin^2 \frac{1}{2}$ t or log Haversine t. We may use Table 45 Bowd. and pick out t or L.A.To. direct or divide by 2 and use Table 44 Bowd. picking out the value according as the Local Time is a.m. or p.m. observation. If we use Table 45 and the time is a.m. we must subtract the value of t in hours, minutes, and seconds from 12 hours or we can use the value from the bottom of the page, subtracting 12 hours from the number of hours. Personally I see no advantage in turning to another table and therefore do not approve of the use of Table 45 in this connection. In dividing by 2 remember that you have to have minus 20 after log $\sin^2 \frac{1}{2}$ t, so that log $\sin \frac{1}{2}$ t must come out after division with -10 after it, therefore before division log $\sin^2 \frac{1}{2}$ t characteristic should be generally 17 or 18 most frequently 18.

Write in the values of t after L.A.To., the difference between G.A.To. and L.A.To. is the Longitude. When L.A.To. is greater than G.A.To. the Longitude is East and when less the Longitude is West, the value coming out in hours, minutes, and seconds, which is converted into degrees and tenths of minutes.

Factor F, Direction of the Line, and True Bearing of Sun—The difference in the Longitudes corresponding to the Latitudes 20′ apart divided by 20′ gives the value of Factor F which is the number of minutes change of Longitude on the Line corresponding to 1′ change of Latitude. Reducing Difference in Longitude to Departure p by Table 2 Bowd., the Tangent of the Direction of the Line is p/20. In order to get the Direction of the Line in minutes of arc, we solve by logarithms and mark the angle with letters as Diff. Long. and Diff. Lat. The True Bearing of the Sun is 90° from the Direction of the Line, East if a.m. and West if p.m., and if a Compass Bearing were taken at the same time, the difference would be the Compass Error from which the Deviation can be obtained by applying the Variation shown by chart.

Time-Azimuth, Compass Error, Deviation—Find the G.A.To. as indicated in the form and by applying the Longitude get the L.A.To. If the azimuth was taken near the time of the Time-Sight, you may apply the difference in Watch Times to the computed L.A.To., adding if taken later and subtracting if taken earlier. The Declination corresponding to G.M.To. is found, the declination used in the Time-Sight being close enough for practical purposes, and with d and L as arguments, according as same or different name, we enter Azimuth Tables H.O. No. 71.

The values of the Time-Azimuth are given for each degree of d and L and ten minute time intervals and is measured from that point of the horizon or pole corresponding to the same name as the Latitude to the Eastward when a.m. to the Westward when p.m. We find in the table the values nearest to coincidence to our d, L, and time and then interpolate to get the corrections to be applied, combining them in accordance with their signs, Cor. L.A.T., Cor. d, and Cor. L, getting Corr. which we apply to the Azimuth Table Azimuth nearest to our three elements, Time, d, and L. The difference between the computed azimuth, Zc, and the observed azimuth Zo is the compass error. It is good practice to convert azimuth into the 0°-360° method, then all you have to remember is, if computed azimuth is greater than observed azimuth the Compass Error is plus and East, if the computed azimuth is less than observed azimuth the Compass Error is minus and West.

Compass Error minus Variation equals Deviation paying attention to their signs or names.

Compass Error and Variation different name or sign Dev. = Compass Error plus Var., the Dev. takes the name or sign of the Compass Error.

Compass Error and Variation same name or sign, the Deviation is their difference, and is the same sign or name as the Compass Error, if Compass Error is greater than the Variation, and different sign or name if Compass Error is less than the Variation.

The rate of change of azimuth of a body when high in altitude, and approaching or receding from the Meridian is quite appreciable for changes in Latitude and Longitude, so that it may be adopted as good practice, that observed bodies for Compass Error within 2° of accuracy, should be less than 30° in altitude

and greater than 3 hours of Meridian Transit, the nearer the Prime Vertical and the lower the altitude the better the results. An error of 2° in the computed direction of the Line of Position, causes approximately 2 miles error for an error of 60 miles in the assumed position, so that as a Practical Navigation consideration we would not lose any sleep over it, but an unknown error of 2° in our Standard or Navigating Compass, which would be the case in an error of 2° in our computed Azimuth, is not acceptable under good Practical Navigation Practice.

EXAMPLE

11 May 1920, a.m., W.To. 9-58-30, sextant hs Sun's lower Limb 55° 52′ 30″, compass Bearing Sun 135° p.s.c., C-W 4-11-34, c.c. 3 m 30 s fast on G.M.T., watch set to approximate L.A.Noon. Course S 82° E p.s.c., speed 9 knots. Required the Line of Position, Sumner Line, and the Deviation of the Compass, Variation by chart − 15° 30′ W, Lat. D.R. 38° 09′ N, Long. D.R. 63° 45′ W, Dip 26 feet.

Adding W.To. 9-58-30 to C-W 4-11-34 = C.To. 2-10-04, subtracting c.c. 3 m 30 s as the chronometer is fast on G.M.T., gives Greenwich Mean Time of Observation 2-06-34 p.m. 11 May 1920, as the Longitude is West.

We pick out d 17° 53.7′ = 17° 53′ 42″ N and Eq. t. plus 3 m 45.7 s, getting P.D. 72° 06′ 18″ as Latitude and Declination are the same name, and G.A.To. 2-10-19.7.

Correcting hs by Table 46 Bowd. gives ho 56° 02′ 51″, adding ho, P.D., and Latitude assumed 38° 00′ 00″, 2s = 166° 09′ 09″, s = 83° 04′ 35″ and s-ho = 27° 01′ 44″.

Log cosec P.D. is .02154, log sec lat. 38° 00′ is .10347, log sec Lat. 38° 20′ is .10545, log cos s 9.08111—10, and for angle 10′ greater log cos 9.07059-10, log sin s-ho 9.65737-10 and for angle 10′ greater log sin angle 10′ greater 9.65994-10. Adding up the logs gives log $\sin^2 \frac{1}{2}$ t 18.86349-20 and 18.85752-20, log sin $\frac{1}{2}$ t 9.43175 and 9.42876, and for t 9-54-34.3 and 9-55-27.3 a.m.

G.A.To. -L.A.To. gives Long. 4-15-45.4 W = 63° 56.4′ W and Long. 2-14-52.4 = 63° 43.1′ W, Diff. Long. 13.3′ E and Diff.Lat. 20′ N, so that Factor F = 13.3/20 = .67′. Departure or p for Diff. Long 13.3′ Middle Latitude 38° Tab. 2 Bowd. is 10.48 miles, log 10.48 = 1.02036, log 20 = 1.30193, so that log tan = 1.02036-1.30193 = 9.71943-10, and angle 27° 39′ North and East is the Direction of the Line. Since the time is a.m. the bearing is East therefore 27° 39′ plus 90° or 117° 39′. The Compass Error = 135°−117° 39′ = 17° 21′ W since computed azimuth is less than observed azimuth, the Var.is 15° 30′ W so that Dev. = 1° 51′ W., the compass Error being greater than the Variation and of the same name.

Before continuing to find the Time Azimuth, I invite comparison with the solution of this problem by the method of Aquino, Chapter 5. Position Point B is Lat. 38° 41.1′ N and Long. 63° 28.7′ W and Direction of the line 209° 08′. The difference in direction of the line by the two methods is 1° 29′, so that difference in compass error is 1° 29′, the most probable deviation is between 0° 22′ and 1° 51′ W. If we move on the Sumner Line to Lat. 38° 41.1′ N a change of 21.1′ N we must move the Longitude to the Eastward 21.1 × .67 = 14.1′ E giving corresponding Longitude 63° 43.1′ W-14.1′ = Long. 63° 29′ W. The corresponding Longitude on the Aquino line is 63° 28.7′ W so that there is a small discrepancy of .3′ of Longitude or about $\frac{1}{4}$ of a mile in the results by the two methods.

This problem was selected especially to practically demonstrate, that the Time-Sight formula is not so limited as has been generally accepted, and that obtaining Compass Error from bodies high in altitude and nearer than three hours of Meridian, gives variable results and therefore undesirable Practical Navigation Practice. This same problem will be solved under the method of St. Hilaire and further comparisons made. The Sumner Line may be run to Noon or any other time by moving the Latitude and Longitude of both position points for True Course and Distance Run in the interval, by Table 2 Bowd. or on the chart, or by moving one position point and drawing a line through it in accordance with the direction of the line of position.

Time-Azimuth—From Table H.O. No. 71, Latitude 38° and d 18° both the same name, L.A.T 9-50, Azimuth = 116° 06′. 119° − 116° 06′ = 2° 54′ the change in azimuth between 9-50 and 10-00 so that change for 9-55 is $\frac{1}{2}$ × 2° 54′ = 87′ and since increasing is plus, 117° 23′ − 116° 06′ = 77′ and 17° 53′ 42″ is 7′ 18″ less than 18° or .105° so that .105 × 77′ = 8′ and increasing so that Cor d = plus 08′. The azimuth for 9-50 Latitude 39°, d 18°, is 117° 23′ and minus 116° 06′ = 77′, so that Cor L = 9/60

SUN SIGHT (TIME SIGHT OR LONGITUDE BY CHRONOMETER)

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Civil Date

I.C.	0° ′ ″	d	17° 53′ 42″ N	Az.Tab. Z	116° 06′	Cor. L.A.T. +	87′	C.Tc.	2 h 12 m 00.0 s
Cor. Table 46	0° 10′ 21 ″		90°	Corr. +	1° 47′	Cor. d +	08′	W.Tc.	10 h 00 m 26 s
Corr.	0° ′ ″	P.D.	72° 06′ 18″	Zc	117° 53′	Cor. L. +	12′	C−W	4 h 11 m 34 s
hs	55° 52′ 30 ″					Corr. +	107′	W.To	9 h 58 m 30 s
ho	56° 02′ 51 ″					ho	56° 02′ 51 ″	C.To.	2 h 10 m 04 s
P.D.	72° 06′ 18 ″	Cosec	.02154		.02154	P.D.	72° 06′ 18 ″	C.C. −	h 3 m 30 s
Lat.	38° 00′ 00 ″	Sec	.10347	+20′	.10545	Lat.	38° 20′ 00 ″	G.M.To	2 h 06 m 34.0 s
	2s)166° 09′ 09 ″						2s)166° 29′ 09 ″	Eqt. +	0 h 3 m 45.7 s
S	83° 04′ 35 ″	Cos	9.08111	+10′	9.07059	S	83° 14′ 35 ″	G.A.To	2 h 10 m 19.7 s
s-ho	27° 01′ 44 ″	Sin	9.65737	+10′	9.65994	s-ho	27° 11′ 44 ″	Zo	135 ° ′
G.A.To.	2h 10m 19.7 s		2)18.86349		2)18.85752	G.A.To.	2h 10m 19.7s	Zc	117 ° 53 ′
L.A.To.	9h 54m 34.3 s	Sin	9.43175	Sin	9.42876	L.A.To.	9h 55m 27.3s	Err.	° ′
λong.	4h 15m 45.4 s	L.A.To. >G.A.To. Long E, <G.A.To Long W.				λong.	2h 14m 52.4s	Pel. H.	° ′
λong.	63° 56.4′ W ″	L.A.T.	38° 00.0′ N″			λong.	° ′ ″	Tr.H.	° ′
λong.	63° 43.1′ W ″	L.A.T.	38° 20′ N″	p =	10.48′	log +	1.02036	Comp. H.	° ′
Δλ	13.3 E p	ΔL.	20′ N			log −	1.30103	Comp. E−	17° 07′ W
Zc = 90° ± Dir. Line	117° 39′	Dir. Line	N 27° 39′ E			tan	9.71933 Factor F .67′	Var−	15° 30′ W
								Dev. −	1° 37′ W

SUN SIGHT (TIME SIGHT OR LONGITUDE BY CHRONOMETER)

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Civil Date

I.C.	0° ′ ″	d	° ′ ″	Az. Tab. Z	° ′	Cor. L.A.T.	′	C.Tc.	h m s
Cor. Table 46	0° ′ ″		90°	Corr.	° ′	Cor. d	′	W.Tc.	h m s
Corr.	0° ′ ″	P.D.	° ′ ″	Zc	° ′	Cor. L.	′	C−W	h m s
hs	° ′ ″					Corr.	′	W.To	h m s
ho	° ′ ″					ho	° ′ ″	C.To.	h m s
P.D.	° ′ ″	Cosec				P.D.	° ′ ″	C.C.	h m s
Lat.	° ′ ″	Sec	+20′			Lat.	° ′ ″	G.M.To	h m s
2s)	° ′ ″					2s)	° ′ ″	Eq. t	0 h m s
S	° ′ ″	Cos	+10′			S	° ′ ″	G.A.To	h m s
s-ho	° ′ ″	Sin	+10′			s-ho	° ′ ″	Zo	° ′
G.A.To.	h m s	2)		2)		G.A.To.	h m s	Zc	° ′
L.A.To.	h m s	Sin		Sin		L.A.To.	h m s	Err.	° ′
λong.	h m s	L.A.To. >G.A.To. Long E, <G.A.To Long W.				λong.	h m s	Pel. H.	° ′
λong.	° ′ ″	Lat.	° ′ ″			λong.	° ′ ″	Tr.H.	° ′
λong.	° ′ ″	Lat.	° ′ ″	p=	′	log+		Comp. H.	° ′
Δλ	′ p ′	ΔL.	20′			log −	1.30103	Comp. E	° ′
Zc = 90° ± Dir. Line =	° ′	Dir. Line	° ′			tan	Factor F ′	Var.	° ′
								Dev.	° ′

THESE FORMS CAN BE PURCHASED (IN PADS OF 25) FROM YOUR DEALER OR BY MAIL FROM J. J. McCRACKEN, NORFOLK, VA.

× 77′ = 12′ and plus for 38° 09′ Latitude. The Total Correction or Corr = 107′ = 1° 47′ plus giving as the computed azimuth 117° 53′.

Compass Error and Deviation—The difference between the computed and observed azimuths is 17° 07′ and since computed azimuth is less than observed the error is West. Comp. E. and Variation being the same name deviation is their difference 1° 37′ and since Comp. E. is the greater it is same name as Comp. E. or West This result is different from the result obtained from the direction of the line in the solution 14′ well within the accuracy of Compass Observations.

PRACTICAL EXAMPLES

(64) 20 May 1920, a.m., W.T. 7-43-03, sextant hs Sun's Lower Limb 35° 30′, I.C. — 1′ 00″, C-W 1-24-08 c. c. 0 m 00 s, Compass Bearing S 70° E p.s.c., Compass Course 125° p.s.c., speed 9.1 knots, Watch set to L.A.T. of the prevous Noon. Dip 36 feet, Variation by chart 19° 15′ W., approximate position Lat. 39° 00′ N, Long. 18° 15′ W.

Required the Line of Position by Sumner Method and the Deviation of the Compass.

(65) 24 May 1920, p.m., W.T. 5-03-28, sextant hs Sun's Lower Limb 22° 57′ 30″, I.C. plus 0′ 30″, C-W 11-39-30, c.c. 2 m 03 s slow on G.M.T.
Compass Bearing of the Sun N 71° W p.s.c. Compass Course 67° p.s.c., speed 10 knots. Required the line of position, Sunmer Line, and the Deviation. Variation by chart 12° 00′ W. Approximate position Lat. 39° 45′ N, Long. 5° 00′ E.

CHAPTER 10

McCracken Form 10

Star—Planet—Moon.
St. Hilaire H. O. No. 200

McCracken Form 10—This form is for the solution of an observation of a Star, a Planet or the Moon, by the use of the U. S. Hydrographic Office Table No. 200 and the Cosine-Haversine method. It should be noted that the G.M.T. and Hour Angle are found as in Aquino. St. Hilaire stops in the time column with the H.A. in hours, minutes, and seconds and there is no further juggling of the Longitude to suit a different t which has been so objectionable in the method of Aquino, this however is the only advantage it has, which is offset by advantages which the Aquino method enjoys in other particulars. We are unable to identify the Star or Planet in the St. Hilaire method, but must adopt the use of some other tables or means of identification. The altitudes are handled in the two methods alike, that is we assume a position near where we think we are and find an altitude and azimuth for that position corresponding to the G.M.T. observation, and then move the line towards or way from the body for the discrepancy between the computed and observed altitude. The form further provides for moving the line to some other time by the use of Table 2 Bowditch and for finding the Compass Error.

G.M.T. of Observation—The Watch is compared with the Chronometer and the Watch Error on G.M.T. obtained. The watch error is added to the Watch Time of observation if slow on G.M.T. and subtracted if fast, to get the G.M.T. of observation. If the G.M.T.is p.m. it is left as it is and the Civil Date is the Local Date, if a.m. G.M.T. 12 hours are added to the hours and the date is Civil Date of the previous day.

Local Sidereal Time—The Right Ascension of the Mean Sun, pages 2-3 Nautical Almanac, for G. M. Noon is picked out and Correction for the mean time interval past Noon which added to G.M.T. gives the Greenwich Sidereal Time. When the Longitude is East it is added, if West subtracted from G.S.T. and the result is the Local Sidereal Time.

The Hour Angle—Since Right Ascension plus Hour Angle equals Local Sidereal Time, then Hour Angle equals L.S.T. minus R.A. so that when R.A.* is greater than L.S.T., the Hour Angle t, is negative, and the body is East of the Meridian and when R.A.* is less than L.S.T., t, is positive and the body is West of the Meridian.

Declination and Right Ascension—The Nautical Almanac gives the Right Ascension and Declination of the Moon and Planets for G. M. Noon and in the case of the Moon for each two hours thereafter, interpolation being required in the case of the Moon and Planets. The change of the R.A. and d of the so-called fixed Stars is so small, that the values are given for G.M. Noon of the first of each calendar month. It should be noted in the case of some stars the seconds and minutes of arc of d are sometimes 60 or more, for instance 1 December R.A. Denebola is given 11-44-61.7 this should be read as 11-45-01.7 and d of Denebola is given plus 44° 60.2′ which should be read as 45° 00.2′ North.

Observed Altitude, ho—The Index Correction, I.C., when given is combined with the Correction obtained from Table 1 H.O. No. 200, remembering in the case of Star or Planet Cor. Table 1 is always minus to get Corr., the total correction, which is then applied to the sextant altitude, hs,to get the observed altitude, ho.

Computed Altitude—t by D.R., d, and Latitude by D.R., are filled in the form, and L varies as d is obtained. When L and d are the same name, L varies as d is their difference, when opposite in name their sum. A little time and labor will be saved by picking out the log cos of d and L, Table 3 H.O. No. 200 first. From Table 4 pick out log hav t, which added to log cos d, log cos L, gives a value of a log hav called and marked with Greek letter sign Theta. It is not necessary to find the angle corresponding to this log hav as the Nat. hav is right alongside it in the table. We therefore look for log hav Theta and pick out Nat. hav corresponding, adding Nat. hav L varies as d giving Nat. hav z or the Nat. hav of the zenith Distance of the body. The altitude is 90°-z, called in the forms hc.

Computed Azimuth—Table 5 is used for this purpose, it being usual to find the azimuth only to the nearest degree, it is a rather laborious task to find the azimuth any closer, therefore it is unsatisfactory to compare with an observed compass azimuth to get the compass error, as the compass error should be correct to the nearest half degree. We enter Table 5 with d and t as arguments and find a number, which is the log sin of the perpendicuar let fall from the body on the Meridian of the observer, or the log sin a of the Aquino method. Since a,d,t, in one triangle are relatively the same as a,h,Z of the other, all we have to do is to look under d for angle equal to h and number equal to log sin a and the angle in the Hour Angle column will be the azimuth.

Moving the Line of Position—As long as we have the direction of the Line of Position, we only move one point of the line around, and then through the point in accordance with the direction of the Line, a line may be drawn on the chart at any time. The Direction of the Line of Position is at right angles to the azimuth of the observed body. After obtaining the computed altitude and azimuth, we compare the computed with the observed, and move the line towards the body if the observed altitude is greater than the computed altitude and away from the body if the observed altitude is less than the computed. This is done in the form by moving the Latitude and Longitude of Position Point A in accordance with the difference in altitudes, giving Position Point B. We then may move Position Point B to any other time by moving it for the run of the ship in the interval and the True Course.

Table 3 H. O. No. 200—This table is rather ingenius in its adaptation for Navigational purposes, It is a logarithmetic table of the sines and cosines of angles to the nearest minute of arc, by interpolating the nearest tenth of minute of arc is attained. The arc measure is further converted into time, the use of heavy type being used to prevent mistakes being made in the work. Under P.P., which means Proportional Part, column is a number in bold or heavy type, which always occurs on a horizontal line with a minute of arc number ending in zero, on the horizontal line with minute of arc ending in 1 is .1 of the number in bold type above it, ending in 2, .2 etc. In interpolation then it is only necessary to find the difference between the function of an angle equal in minutes to your angle and an angle one minute greater, look for number in bold type equal to it, and under it on horizontal line with minute ending in digit equal to the tenths of minutes is the amount to be added or subtracted in interpolating. In the case of cosines this value is always subtractive as the angle increases. For instance we desire the log cos 8° 46.2′. On page 47 H. O. No. 200 is the angle 8° and for 46′ of arc reading from the bottom, since cosines are at the bottom of the page, we get 9.99490 and for 47′ 9.99488 the difference being 2 decreasing, looking in P.P. column for 2 in bold type we find that opposite 2 is 0, 12 is 0, 22. is 0, etc, therefore the difference for .2′ of arc is neglible.

Table 4 H. O. 200—Table 4 is a table containing the log Haversine and Natural Haversine to nearest second of time where the angle is expressed in time measurement and nearest 15″ of arc when expressed in arc measurement. The vertical column instead of being for each degree arc measurement is for each minute of time measurement or fifteen minutes of arc measurement. In the vertical seconds of time column after every 4 s increase there is in bold type the corresponding increase in arc measurement. For instance page 78, 2-51-04 time is 42° 45′ plus 1′ arc or 42° 46′. It is usual to work in time to the nearest tenth of a second by means of interpolation. Thus log hav 3-14-10.6 is obtained by interpolation between log hav 3-14-10 and 3-14-11, the difference is 7 and $.6 \times 7 = 4.2$ so we add 4 as the value is increasing to log hav 3-14-10, 9.22779, getting 9.22783. In the case of getting nat hav Theta from the log hav we do not have to get the angle itself, we merely interpolate thus, log hav 9.12364 the nearest given in the Table is 9.12365 and the next less 9.12357 giving a difference 8 the corresponding difference hav is 3 and since 9.12364 is one less than 9.12364, $\frac{1}{8} \times 3 = .36$ which being less than .5, we call the nat hav .13294.

Aquino versus Cosine-Haversine St. Hilaire—It should appear by this time that the student or investigator should be convinced that the Aquino method H. O. No. 200 is superior to the St. Hilaire method H.O. No. 200 for Practical Navigation purposes, but we will compare the two briefly. In the Aquino method we use one table against three in the St. Hilaire and in case of identification four. In Aquino we have two interpolations, in St. Hilaire seven, and if the azimuth as obtained by Table V is desired to be used for Compass Error, probably three more interpolations for St. Hilaire. In using printed forms with the precepts printed at the bottom of each form, the necessity of changing the first assumed Longitude in the case of Aquino is its only handicap, and that may be mastered for all time by about one-half hour study.

Considering the fact that the French used the St. Hilaire method over forty years before its adoption by the skilled navigators of the U. S. Navy and later by others, it is not surprising that although the Method of Aquino has been available for use in the United States for over eight years, to my certain knowledge, it has so few users.

No Navigating Officers of a ship in our Battle Fleet have ever got by on the so-called eight o'clock Navigation, permitted in our Merchant Marine, within my experience in the Navy of over twenty-one years. The conditions of operation and rapid expansion have no doubt had their effect on the requirements for license, so that as the second officer is supposed to be the Navigating Officer we should start with his examination for license, and abandon the attempted location of ship by Latitude and Longitude and insist on their location by intersection of Lines of Position.

EXAMPLE

9 May 1920, p.m., W. T. 7-13-02, observed the altitude of a large star or planet 25° 20.8′ by sextant, bearing 130° p.s.c., Compass Error 5° 00′ W, height of eye 36 feet.

Chronometer time comparison, C.Tc., 12-14-00, chronometer correction, c.c., 0 m 37 s fast on G.M.T., watch time comparison, W.Tc., 7-32-49. The approximate position Lat. 37° 15′ N, Long. 71° 30′ W. Compass Course 89°, speed 11 knots. Identify the star or planet, find the line of position for 8:00 p.m. and the Compass Error.

G.M.To. and G.M.As.To—The c.c. is subtracted, since fast, from C.Tc. giving G.M.Tc. 12-13-23 and since Longitude is West we subtract W.Tc. getting W. Err. 4-40-34 slow on G.M.T. The W. Err., since slow, is added to the W.To. to get G.M.To. 11-53-36 and since Local Time is p.m. the G.M.T. is p.m. being less than twelve hours so G.M. As.T. and G.M.T. are the same.

L.S.T.—The R.A.Mean Sun is picked out for G.M.Noon 9 May and Cor. for mean time interval 11-53.6 giving G.S.T. 15-03-32.4. Since the Longitude is West we subtract it from G.S.T. giving L.S.T. 10-17-32.4.

Observed Altitude—The correction Table 1 dip 36′ is 8.0′ which subtracting from hs gives ho 25° 12.8′.

Identification of the Body—Astronomical Bodies are identified by their R. A. and Declination. The known elements are the observed altitude and the G.M.T.of the observation. The observed azimuth is known within the accuracy of the compass error and the approximate Latitude and Longitude are known. An examination of Table 5 using h and Z as arguments only gives the value log sin of the perpendicular let fall from the body on the Local Meridian so that we cannot identify the body from this table alone. We are then forced to resort to some star identification table or some other method of identification table. As long as we have H.O. No. 200 we turn to Table 6 which is the Aquino table. If then we must use Aquino or something similar for identification why waste the time of solution by St. Hilaire, but solve the problem from the same table used in identification. Instead of using Table 5 we turn to Table 6. The True Azimuth is 125° or S 55° E and h 25 12.8 The coincidence is a = 48° and C = 51° greater than L and the azimuth greater than 90° so that b = C-L = 51° − 37° = 14° and d and L contrary named. For b we get d 9° 19′ S and t = 48° 51 = 3-15-24 less than 90° and negative since the body is East. Adding to the L.S.T 10-17-32.4 gives R.A. 13-32-56.4.

Looking in the Nautical Almanac page 94-95, Spica R.A. 13-21-01.6 and d 10° 44.9′ S, so that it might have been Spica, in view of the doubt as to star or planet we examine the Planets and find page 83 N.A. Mars R.A. 13-32-17 and d 8° 48.1 S. The Star then is the Planet Mars.

d and R.A. Mars—May 9 1920, G.M.Noon R.A. 13-32-17 and d 8° 48.1′ S, for 11.9/24 day additional = .5 nearly we subtract .5 × 68 = 34 from R.A. giving 13-31-43 and .5 × 37 = 1.9′ from d giving 8° 46.2′ S so that R.A. is 13-31-43 and d 8° 46.2′ S.

Hour Angle—Applying the R.A. to the L.S.T. gives the H.A. 3-14-10.6 and since R.A. is greater, it is negative or East.

Computed Altitude—Since L and d are different named, L varies as d = 46° 01.2. Picking out log cos d and log cos L from Table 3 and log hav t from Table 4 and adding gives Log hav Theta 9.12364.

McCRACKEN FORM 10

STAR SIGHT (SAINT HILAIRE) H. O. No. 200.

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Civil Date

		t.D R.	3h 14m 10.6s	log hav	9.22783	Num. Tab. V.	9.86904		C. Tc.	12h 14m 00. s
I. C.	0°	d	8° 46.2′	log cos	9.99490	ho = d	° ′		– C. C.	h 0m 37. s
Cor. Tab. I	0° 08.0′	L. D. R.	37° 15.0′	log cos	9.90091	Zc.	S 55° ′ E		G. M. Tc.	12h 13m 23. s
Corr. –	0° 08.0′			⊖log hav	9.12364	Zc.	125° ′		W. Tc.	7h 32m 49. s
hs	25° 20.8′			⊖nat hav	.13294				W. Err.	4h 40m 34. s
ho	25° 12.8′	L ∽ d	46° 01.2′	nat hav	.15280				W. To.	7h 13m 02. s
hc	25° 22.3′	Z	64° 37.7′	nat hav	.28574			W. To.	G. M. To.	11h 53m 36. s
Δh	° 9.5′	L. A.	37° 15.0′	λA.	71° 30.0′			1st * W. To.	R. A. M.⊙	3h 07m 59.1s
Δh	9.5′	Δ L.	° 05.5′ N	Δλ	° 9.7′ W	Dir.	305°	Δ W. T.	Cor.	h 1m 57.3s
Factor F	′	L. B.	37° 20.5′ N	λB.	71° 39.7′ W	Dir.Line	35°	N. A. Page 2-3 Cor. Δ W.T.	G. S. T.	15h 03m 32.4s
Dist. to 8.00 P.M.	8.8′	Δ L.	° .9′ N	Δλ	° 11.0′ E	Tr. C.	84°	1st * L. S. T.	λD.R.	4h 46m 00. s
Obs. Zo.	130° 0.0′	L. P.	37° 21.4′ N	λP.	71° 28.7′ W	W. T.	8h 00 A.M. P.M.		L. S. T.	10h 17m 32.4s
Zc.	125° 0.0′								R. A. *	13h 31m 43. s
Error	5° 00.0′ W								– t D. R.	3h 14m 10.6s
Pel. H.									t D. R.	h m s
Tr. H.	° ′									
Comp. H.	° ′									
Comp. Err.	° ′									
Var.	° ′									
Dev.	° ′									
S. H.	° ′									

Note—For identifying Star, use McCracken Star Identification Protractor in connection with H. O. No. 2100 between 30° N or S and 60° N or S Lat. as Navigation Stars are large d to nearest 5° and Z to nearest 10° are sufficiently accurate for identification.

STAR SIGHT (SAINT HILAIRE) H. O. No. 200.

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Civil Date

		t.D R.	h m s	log hav		Num. Tab. V.			C. Tc.	h m s
I. C.	0° ′	d	° ′	log cos		ho = d′	° ′		C. C.	h m s
Cor. Tab. I	0° ′	L. D. R.	° ′	log cos		Zc.	° ′		G. M. Tc.	h m s
Corr. –	0° ′			⊖log hav		Zc.	° ′		W. Tc.	h m s
hs	° ′			⊖nat hav					W. Err.	h m s
ho	° ′	L ⤷ d	° ′	nat hav					W. To.	h m s
hc	° ′	Z	° ′	nat hav				W. To.	G. M. To.	h m s
Δh	° ′	L. A.	° ′	λA.	° ′			1st * W. To.	R. A. M. ⊙	h m s
Δh	′	Δ L.	° ′	Δλ	° ′	Dir.	°	Δ W. T.	Cor.	h m s
Factor F	′	L. B.	° ′	λB.	° ′	Dir.Line	°	N. A. Page 2-3 Cor. Δ W.T.	G. S. T.	h m s
Dist. to	′	Δ L.	° ′	Δλ	° ′	Tr. C.	°	1st * L. S. T.	λD.R.	h m s
Obs. Zo.	° ′	L. P.	° ′	λP.	° ′	W. T.	h m A.M./P.M.		L. S. T.	h m s
Zc.	° ′								R. A. *	h m s
Error	° ′								t D. R.	h m s
Pel. H.	° ′								t D. R.	h m s
Tr. H.	° ′									
Comp. H.	° ′									
Comp. Err.	° ′									
Var.	° ′									
Dev.	° ′									
S. H.	° ′									

Note—For identifying Star, use McCracken Star Identification Protractor in connection with H. O. No. 2100 between 30° N or S and 60° N or S Lat. as Navigation Stars are large d to nearest 5° and Z to nearest 10° are sufficiently accurate for identification.

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Adding the nat hav Theta and nat hav L varies as d we get nat hav z .28574 and z 64° 37.7′ and hc = 90° − 64° 37.7′ = 25° 22.3′.

Computed Azimuth—Entering Table 5 with d and t as arguments we find the value 9.86904 and this value again in a vertical column equal to h gives Zc 55° and since d is S and t is negative, we mark it S and E giving Zc 125°.

Compass Error—The difference between the observed and computed bearing is 5° and since observed is greater it is West. The compass error is 5° W.

Moving the Line—The difference between computed and observed h is 9.5′ and since observed is less we move away from Mars or the reverse of its True Bearing which is 305° by use Table 2 Bowd. giving Position Point B Lat. 37° 20.5′ N and Long. 71° 39.7′ W. The Direction of the Line is 35° and Factor F the movement of Longitude corresponding to change of 1 minute Latitude Table 47 Bowd. is .88′. The speed of the ship is 11 knots and from time of observation to 8:00 p.m. is 47′ = .8 hour so .8 × 11 = 8.8 miles. The Compass Course is 89° Compass Error 5° W, therefore True Course is 84°, moving Position Point B 8.8 miles 84° Table 2 Bowd. gives Position Point P at 8:00 p.m. Lat. 37° 21.4′ N Long. 71° 28.7′ W. Plotting Position Point P on chart and drawing line through it Direction 35° we have the Line of Position moved to 8:00 p.m.

PRACTICAL EXAMPLES

(66) At W.To. 7-13-32 p.m. 11 May 1920, observed hs of star 39° 16′ bearing 115° p.s.c., Comp. Err. about 19° W, dip 39′, approximate position Lat. 38° 30′ N, Long. 61° 30′ W, W. Err. 4-08-10 slow G.M.T.
Required the name of the star, the line of Position St. Hilaire and the Compass Error.

(67) 16 May 1920, morning twilight, approximate position Lat. 40° 00′ N, Long. 39° 15′ W, observed two stars as follows:
W.T.3-53-25 a.m., hs 9° 20,5′, bearing 149° p.s.c.
W.T. 3-55-30 a.m., hs 17° 33′, bearing 26° p.s.c.
The dip was 39′, estimated compass error 15° W, W.Err. G.M.T. 2-52-04 slow.
Required the identification of the stars by the method of Aquino and the Astronomical fix by St. Hilaire.

(68) 5 June 1920 p.m., Lat. by D.R. 42° 45′ N, Long. by D.R. 3° 55′ E, dip 39′, W.Err. 1-03-48 fast G.M.T.
W.T. 8-56-37 p.m. observed Mars hs 38° 40′ and W.T. 8-57-34 p.m. observed Jupiter hs 33° 43′.
Required the astronomical fix by method St. Hilaire.

CHAPTER 11

McCracken Form 11

Sun Sight.
St. Hilaire H. O. No. 200.

Greenwich Mean Time—The watch is compared with the chronometer either before or after taking the observation. The chronometer time of comparison, C.Tc., is corrected for the chronometer correction, adding if slow subtracting if fast, obtaining the Greenwich Mean Time of Comparison, G.M.Tc. The watch time of comparison is subtracted from G.M.Tc. in West Longitude and the resultant Watch Error is slow on G.M.T., in East Longitude the G.M.Tc. is subtracted from W.Tc. and the W.Err. is fast on G.M.T. When W.Err. is fast subtract from watch time of observation, W.To., and when slow add to W.To. to get Greenwich Mean Time of observation, G.M.To. When the G.M.To. is p. m. the Greenwich Astronomical Mean Time and Greenwich Time are the same, when the G.M.T. is a. m. add 12 hours and use the date of the previous day for G.M.As.T.

Declination and Equation of Time—In the Nautical Almanac pages 6-29 is given the Declination and Equation of Time of the Sun for every two hours from Greenwich Mean Noon and at the bottom of each Astronomical Date is the Hourly Difference to be used as a multiplier in interpolating for the G.M.T. interval between the two hour periods. In interpolating it is best for the beginner to adopt the additive practice, that is pick out the function for the nearest value always less, for instance if we had 9.9 hours the nearest value less would be 8 so we would multiply the H.D. by 1.9 and add to the value of Declination and Equation of Time if increasing in value and subtract if decreasing in value. Experts would in this case have used the subtractive method, that is they would have subtracted 9.9 from 10 taken .1 of the H.D. and applied to the values of d and Eq. t. given for ten hours. When d is marked plus it is North and minus it is South. The sign in front of the Eq. t. shows how it is to be applied to Mean Time to get Apparent Time. We pick out then the d and Eq. t. corresponding to Greenwich Mean Astronomical Time, and fill them in the places provided for them in the forms.

Local Hour Angle, t by D.R.—Applying the Equation of Time to the G.M.To. in accordance with its sign gives the G.A.To, the Greenwich Apparent Time of observation. When the Longitude is West subtract and when East add it to G.A.To. to get L.A.To. or t by D.R. as given in the form. If the Local Time is a.m. and six hours or greater we subtract from twelve hours and also if p.m. and greater than six hours which is the reason for the provision of two places in the form for t by D.R. this value of t is also placed at the top of the second vertical column.

L varies as d—When Declination and Latitude are the same name L varies as d is their difference and when of different name their sum.

Computed Altitude—From Table 3 H.O. No. 200 pick out log cos d and log cos Latitude by D.R. and from Table 4 log haversine t by D.R. and adding get log hav Theta. Pick out the nat hav corresponding to log hav Theta and the nat hav L varies as d adding and getting nat hav of the zenith Distance of the Sun, z. The altitude hc is 90°-z.

The use of Table 3 is explained in Chapter 10.

Computed Azimuth—With d and t as arguments enter Table 5 and set down the number, which is a logarithm, as provided in the form. Then with ho used as Declination in the table, find the same value of logarithm in the right hand vertical columns, and on the same horizontal line under Hour Angle column in degrees is the azimuth measured from the Meridian. It is identified as East when t is negative or a.m. in the case of the Sun, and West when t is positive or p.m. in the case of the Sun. When the body is near the prime vertical it is sometimes confusing to determine whether to mark it the same or different name from the Latitude. At the beginning of the Table a rather complicated explanation is prefixed but most of us would determine it from the compass bearing, unless in grave doubt as to the compass error being several degrees wrong. This feature to a practical Navigator only emphasizes the advantages of

the Aquino method where there is no doubt with your precepts printed at the bottom of your form. My recommendation to you is to either use Azimuth Tables H.O. No. 71 or change your time of taking observations.

Compass Error—The difference between the computed and observed azimuths is the compass error. It is best to reduce all bearings to the 0°-360° method, when the observed bearing is greater than the computed the compass error is West or minus, when it is less than the computed bearing the compass error is East or plus.

Deviation—The difference between the Variation and Compass Error is the Deviation when they are the same name and their sum when of different name. When of the same name if Compass Error is greater the Deviation is the same name as Compass Error and if Compass Error is less than Variation the Deviation is opposite in name. When Compass Error and variation are different named the Deviation is their sum and has the same sign or name as the Compass Error. Variation plus Deviation equals Compass Error due regard being paid to the signs or letters.

Moving the Line of Position—By moving a position point on the line either on the chart or by Table 2 Bowditch we draw through the position point arrived at a line in the direction of the Line of Position. After obtaining the computed altitude we must move Position Point A towards the Sun if observed altitude, ho, is greater than the computed altitude, and away from the Sun if observed altitude is less than the computed, the direction of movement being indicated by the computed azimuth True of the Sun. In the form the difference in h is set down and is moved by Table 2 Bowd. with the direction of movement as a True Course and the difference in altitude in minutes of arc as miles of distance. Do not forget to convert the Dep into minutes of Longitude by the Middle Latitude method. This gives Position Point B through which drawing a line at right angles to the True Bearing of the Sun fixes the Line of Position by observation. The form further provides for moving the Position Point B to some other time by use of Table 2 Bowd., such as Noon, 8:00 a.m., 8:00 p.m. etc.

Aquino versus Cosine-Haversine St. Hilaire—The two methods from a Practical Navigator's standpoint have been compared in Chapter 10 and all that was said there applies to observations of the Sun, except we do not have to identify the Sun in either method.

EXAMPLE

11 May 1920, a.m., W.To. 9-58-30, sextant hs Sun's Lower Limb, 55° 52.5′, W. Err. 4-08-04 slow on G. M.T., Compass Bearing Sun 135° p.s.c., Compass Course S 82° E p.s.c., speed 9 knots, watch set to L.A.T. Required the Line of Position run to L.A.Noon and the Deviation, the Var. by chart 15° 30′ W., Lat. by D.R. 38° 09′ N, Long. 63° 45′ W.

G.M.To—Adding the W.Err. since slow 4-08-04 to W.To. gives G.M.To. 2-06-34. Since the civil date is a.m. 11 May and the Longitude West the Greenwich Time is later than the civil time, therefore it must be either about 2:00 p.m. 11 May or 2:00 a.m. 12 May at Greenwich. It cannot be a.m. Greenwich Time for if we assume the maximum of West Longitude, 12 hours, and subtract from 2:00 a.m. we would get a civil date of p.m. whereas we know from the problem the civil time is a.m. We therefore mark G. M.To. as p.m. which gives G.M.As.T., the same as G.M.To. that is both times are the number of hours etc. since Greenwich Mean Noon.

Declination and Equation of Time—Looking in the Nautical Almanac for 11 May 1920 we find for 2 hours after G.M.Noon d 17° 53.7′ N and Eq. t. plus 3 m 45.7 s. 6 m 34 s is 6.57/60 = .11 hours, the H.D. for d is .6 which multiplied by .11 = .066 = .1 to nearest tenth of a minute so that as d is increasing in value we add .1′ to 17° 53.7′ giving for d plus or N 17° 53.8′. The H.D. for the Eq. t. is .1 which multiplying by .11 gives .011 which is .0 to the nearest tenth so we use as Eq. t plus 3 m 45.7 s.

t by D.R.—Applying the Eq. t. plus to the G.M.To. we get G.A.To. 2-10-29.7. The Longitude being West we subtract it from G.A.To. getting L.A.To. or t by D.R. In order to use the Cosine-Haversine tables we must get this value in time from the Meridian so that as the time is a.m. we subtract from 12 hours getting 2-04-30.3 and since the Sun is East in the morning the Hour Angle is negative.

L varies as d—The Latitude and d having the same name L varies as d = L − d = 20° 15.3′.

Computed Altitude—From Table 3 bottom of the page we find log cos d = 9.97849 − .00003 = 9.97846 and log cos L = 9.89564. From Table 4 we find log hav t = 8.85721 plus .3 × 13 = 8.85725. Adding up log hav t, log cos d, log cos L we get log hav Theta = 8.73135. Without picking out the value of Theta we find its nat hav = .05385 plus 2 × 13/14 = .05387 to the nearest tenth. The nat hav 20° 15.3′ = .03090 plus .3 × 5 = .03092 to the nearest tenth. Adding nat hav Theta to nat hav L varies as d we get nat hav z = .08479 and z 33° 51.5′. Computed altitude = 90° − z = 56° 08.5′.

Computed Azimuth—Table 5 Hour Angle 2-04, d 17° 30′ number 9.69126, d 18° number 9.69005 and difference is 121 therefore for d 17° 53.4 we get 9.69126 − .8 × 121 = 9.69029. The difference between the numbers for 2-04 and 2-08 for d 17° 30′ is 237 and 30 s = ⅛ × 4 m therefore we add as the number is increasing ⅛ × 237 = 30 to 9.69029 = 9.69059 and we place this number after Num. Tab. V. in the form. We now look for an angle in our Declination equal to the observed altitude 56° 02.9′ looking under 56°. The nearest number less is 9.68938 and greater is 9.69349 giving azimuths 61° and 62° so we know our azimuth is between the two. Now when only desiring the bearing of the line from a practical standpoint it makes little difference whether you take 61 or 62 but for compass error it does. By interpolation we get 60 × 121/411 = 18′ so we use as azimuth 61° 18′. We should have interpolated again for 02.9′ as our altitude is greater than 56° but there is no practical advantage in so doing. I cannot help but remark again that the use of Aquino obviates all this interpolation and extra labor.

Position Point B—The difference between the computed and observed altitude is 5.6′ and since observed is less we move it away from the Sun or North and West. From Table 2 Bowd. we get Lat. 2.7′ and Diff. Long. 6.2′ W which we apply to Position Point A giving Position Point B Lat. 38° 11.7′ N and Long. 63° 51.2′ W.

Line of Position L.A.Noon—Since Noon is 12 o'clock and our observation was taken practically at ten o'clock we have two hours run to Noon at nine knots giving 18 miles and the Compass Course is S 82° E and using compass error 16° W gives True Course 82°. We move Position Point B 18 miles 82° giving Lat. 38° 14.2′ N and Long. 63° 28.6′ W and the Direction of the Line is 29° or 209° at right angles to the True Bearing of the Sun at observation.

PRACTICAL EXAMPLES

(70) 20 May 1920, a.m., W.T. 7-43-03, sextant hs Sun's Lower Limb 35° 30′, I.C. − 1′ 00″, W.Err. 1-24-08 slow on G.M.T., compass bearing S 70° E p.s.c., Compass Course 125° p.s.c., speed 9.1 knots, Watch set to L.A.T. of the previous Noon.

Required the Line of Position by the Method of St. Hilaire run to 8:00 a.m. watch time and the Deviation of the Compass. Variation by chart 19° 15′ W. Approximate Position Lat. 39°00′ N, Long. 18° 15′ W. Height of eye 36 feet.

(71) 24 May 1920, p.m., W.T. 5-03-28, sextant hs Sun's Lower Limb 22° 57′ 30″, I.C. plus 0′ 30″, W.Err. 0-18-27 fast on G.M.T. compass bearing Sun N 71° W p.s.c. Compass Course 67° p.s.c. speed 10 knots.
Required the Line of Position run to 8:00 p.m. and the Deviation, Variation by chart 12° 00′ W. Approximate position Lat. 39° 45′ N, Long. 5° 00′ E, Dip 36 feet.

McCRACKEN FORM 11

SUN SIGHT (SAINT HILAIRE) H. O. No. 200

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Civil Date

		t D.R.	2 h 04 m 30.3 s	log hav	8.85725			Num Tab. V	9.69059	C.Tc.	h m s
I.C.	0° ′	d	17° 53.8′ N	log cos	9.97846			ho = d′	56° 28.5′	C.C.	h m s
Cor. Tab. I	0° 10.4′	L.D.R.	38° 09.0′ N	log cos	9.89564			Zc.	S 61° 18.0′ E	G.M.Tc.	h m s
Corr.	0° 10.4′			⊖ log hav	8.73135			Zc.	118° 42′	W.Tc.	h m s
hs	55° 52.5′										
				⊖ nat hav	.05387			Obs. Zo.	135° 00′	W. Err.	4 h 08 m 04 s
ho	56° 02.9′	L ∽ d	20° 15.3′	nat hav	.03092			Err.	16° 18′ W	W.To	9 h 58 m 30 s
hc	56° 08.5′	z	33° 51.5′	nat hav	.08479			Pel. H.	15° 30′ W	G.M.To	2 h 06 m 34 s
Δh	° 5.6′	L.A.	38° 09.0′ N	λA.	63° 45 ′ W			Tr.H.	° ′	Eq. t +	h 3 m 45.7 s
Δh	° 5.6′	ΔL.	° 2.7′ N	Δλ	° 6.2′ W	Dir.	299°	Comp. H.	° ′		
										G.A.To	2 h 10 m 29.7 s
Factor F.	.70	L.A.	38° 11.7′ N	λB.	63° 51.2′ W	Dir. Line	29°	Comp. Err.	16° 18′ W	λD.R.	4 h 15 m 0.0 s
Dist. to	18 ′	ΔL.	° 2.5′ N	Δλ	22.6′ E	Tr.C.	82°	Var.	15° 30′ W		
										t D.R.	9 h 55 m 29.7 s
W.T. h m	a.m.	L.P.	38° 14.2′ N	λP.	63° 28.6′ W			Dev.	0° 48′ W	t D.R.	2 h 04 m 30.3 s
	p.m.							S.H.	° ′		

McCRACKEN FORM 11

SUN SIGHT (SAINT HILAIRE) H. O. No. 200

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Civil Date

		t D.R.	h m	s log hav		Num Tab. V		C.Tc.	h m s
I.C.	0° ′	d	° ′	log cos		ho = d′	° ′	C.C.	h m s
Cor. Tab. I	0° ′	L.D.R.	° ′	log cos		Zc.	° ′	G.M.Tc.	h m s
Corr.	0° ′			log hav		Zc.	° ′	W.Tc.	h m s
hs	° ′			⊖ nat hav		Obs. Zo.	° ′	W. Err.	h m s
ho	° ′	L ∽ d	° ′	⊖ nat hav		Err.	° ′	W.To	h m s
hc	° ′	z	° ′	nat hav		Pel. H.	° ′	G.M.To	h m s
Δh	° ′	L.A.	° ′	λA. ° ′		Tr.H.	° ′	Eq. t	h m s
Δh	° ′	ΔL.	° ′	Δλ ° ′	Dir. °	Comp. H.	° ′	G.A.To	h m s
Factor F.		L.B.	° ′	λB. ° ′	Dir. Line °	Comp. Err.	° ′	λD.R.	h m s
Dist. to	′	ΔL.	° ′	Δλ ′	Tr.C. °	Var.	° ′	t D.R.	h m s
W.T.	h m A.M. P.M.	L.P.	° ′	λP. ° ′		Dev.	° ′	t D.R.	h m s
						S.H.	° ′		

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CHAPTER 12

McCracken Form 12

Amplitude—Time Azimuth—High Water

Amplitude—The amplitude of a body is its angular distance from the East point of the horizon at rising and the West point at setting. It is marked East or West so many degrees and minutes North or South as the case may be.

Determination of Proper Time of Observation—Due to the fact that change in Azimuth is almost inappreciable at rising or setting, and that the time from the top limb to lower limb and vice versa cutting the visable horizon is very rapid; for Practical Navigation purposes the exact instant of observation is not very important as long as it occurs between the interval of the cutting of the visable horizon by the limbs of the body.
It is usual however to estimate with the eye, in the case of the Sun, when the center of the Sun is in the visable horizon and take the observation at that instant.

Marking the Amplitude—There is never any doubt about the East and the West, as we know all bodies rise in the East and set in the West. When the body rises or sets near the Prime Vertical there is at times some doubt about the marking North or South.
All we have to do is to mark it the same name as the declination of the body observed.

The Compass Observation—As the Compass is marked in degrees from the North Point or from both the North and South Points, do not forget to convert the observation into angular distance North or South of the East and West Points of the Compass.

Amplitude by Logarithms—Write in after Lat. the Latitude of the observation and after d the Body's Declination. The summation log sec L and log sin d is the log sin of the Amplitude.

Amplitude by Table 39 Bowditch—Table 39 Bowditch is a table solution of the formula sin d sec L = sin Amplitude. The Latitudes are to the nearest whole degree and declination to half degrees. Table 40 is a further refinement which is explained in the Bowditch page 513.

Compass Error—The difference between observed Amplitude and Computed Amplitude is the Compass Error. When the computed is to the right of the observed the error is East and when to the left the error is West.

Time Azimuth—The L.A.To. in the case of the Sun or Hour Angle in the case of a Star, Planet or Moon must be found. As a Practical Navigation problem the Sun is invariably used by the experienced Navigators, so the form provides for the use of the Sun.

H. O. No. 71 is used for this purpose, which has Latitude, Time and Declination as arguments. To get the best results the body should be below 30° in altitude and not nearer than 45° of the Meridian.

The nearest value of the Azimuth from the Table is found less than our Latitude, Declination, and Time elements and a Correction is applied and obtained by the principle of interpolation.

Compass Error—A comparison of the observed and computed Azimuth gives the Compass Error and is marked East or West according to whether the Computed Azimuth is to the right or left of the observed Azimuth.

High Water Lunar Interval or Port Establishment—The Lunar Tidal Interval is the interval from the Moon's Meridian Passage to the occurrence of High Water at any particular place. The practice in obtaining this Port Establishment is not uniform as a theoretical proposition, but for Practical Purposes, as the time of High Water to the nearest five minutes is sufficient, the H. W. Full and Change is close enough.

Determination of the Use of Upper or Lower Transit—Due to the addition of the Port Establishment to the time of Meridian Transit of the Moon, in order to get p.m. or a.m. High Water Calendar Date, it is important to determine whether to use the time of Upper or Lower Transit. For Practical Purposes the lower Transit is assumed to occur half way between two successive Upper Transits. The Nautical Almanac gives the G.M.T. of Upper Transit at Greenwich, England, which has to be corrected for Longitude to reduce it to Local Meridian Transit. This correction may be ignored in determining whether to use Upper or Lower Transit.

In the form we write in the Greenwich Upper Transit for Astronomical date corresponding in number to the Civil Date whose a.m. and p.m. High Water is desired. By adding the Port Establishment we get the approximate Local Astronomical Time of approximate High Water. If the hours are greater than twelve then the time is a.m. and upper transit gives a.m. High Water and Lower Transit p.m. High Water. If the hours are less than twelve then the Approximate High Water Time is p.m. and Upper Transit gives p.m. High Water and Lower Transit a.m. High Water.

If the numerical number of days for approximate High Water comes out the same as our Calendar date, we use the Astronomical date of the civil date for Upper Transit, and the mean of this date and the day after for Lower Transit, otherwise we use the astronomical date of the day before the civil date for Upper Transit, and the mean of the Upper Transit of the day before and the civil date, for time of Greenwich Lower Transit.

Time of High Water—Fill in the form the Astronomical day, hours, and minutes of the Greenwich Upper Transits, determined by percepts of the previous paragraph under proper column that gives High Water after Lower Transit. If the proper column is a.m. do not fill in after G.M.T. Gr. Transit in pm. column and vice versa.

Add the Upper Transit days, hours, and minutes and divide by two which gives G.M.As.T. of Greenwich Lower Transit which is marked in the form G.M.T. Gr. Transit. Now fill in the other column, the time of upper Transit which gives High Water on the calendar date desired.

We next correct by Table 11 Bowd. for Longitude to reduce to L.M.As.T. of Transits. Adding the Port Establishment gives the L.M.As.T. of High Water which by inspection is written in reduced to civil time. Applying the Watch Error on L.M.T. gives W.T. High Water.